Central venous surface anatomy: a critical reappraisal

Samuel J. M. Hale

A thesis submitted in fulfilment of the requirements for the degree of Bachelor of Medical Science with Honours

at the University of Otago, Dunedin, New Zealand.

2011
Abstract

Background: Surface anatomy is an essential part of safe clinical practice, and a key component of physical examination. Our knowledge of surface anatomy has been primarily derived from cadaver studies, with all their associated limitations. Surface anatomy needs to be reappraised in the light of modern imaging techniques in healthy living subjects to ensure that it is fit for purpose in the modern evidence based era.

Aims: (i) To determine the consistency with which surface anatomy relevant to cardiothoracic medicine and surgery is reported in contemporary anatomical reference texts, and (ii) to establish evidence based surface markings for the central veins using computerised tomography and ultrasound.

Methods: (i) Major surface anatomy landmarks reported in ten contemporary anatomical reference texts and three popular clinical examination texts were analysed to assess consistency. These were compared to evidence based landmarks derived from scientific studies. (ii) 103 computerised tomographic (CT) scans of the chest (52 female; mean age 64 years [range 19–89 years]) were analysed to establish evidence based surface markings for the central veins and the cardiac apex. In addition, the surface anatomy of the subclavian veins was examined bilaterally using ultrasound in 50 healthy volunteers (25 female; mean age 35 years [range 19–68 years]; mean BMI 24.0 [16.5–37]). The relationship of the subclavian vein to the clavicle was examined both with and without passive shoulder retraction with 10° of head down tilt.
**Results:** (i) There are numerous inconsistencies in the reporting of many surface anatomy landmarks both between and within reference texts. Few texts address variation with age, gender, ethnicity, body habitus, posture and phase of respiration. Clinical examination texts contain comparatively little surface anatomy. (ii) In most living adults, the brachiocephalic veins are formed posterior to the ipsilateral sternoclavicular joint, the superior vena cava is formed posterior to the right second costal cartilage and enters the right atrium behind the right fourth costal cartilage. The azygos vein typically joins the superior vena cava at the level of the lower half of the fifth thoracic vertebra, 2 cm below the sternal angle. The cardiac apex lies on average in the left fifth intercostal space close to the midclavicular line, about 9 cm from the midline. The subclavian vein lies closest to the clavicle approximately 7 cm from the midline; it has an average diameter of 10 mm, decreasing by approximately 10% after passive shoulder retraction. Age, gender and body mass index affect these variables.

**Conclusions:** Whilst some commonly accepted thoracic surface markings appear to be reliable when examined in living subjects using modern imaging techniques, others are inaccurate. This is not only relevant to ensuring that modern anatomy teaching is fit for purpose but also important for practical procedures such as central venous catheterisation. Rather than improving successful subclavian vein puncture, passive shoulder retraction may reduce the chances of successful catheterisation by reducing venous diameter. Surface anatomy must be reappraised in living subjects using modern imaging techniques if it is to be accurate and remain useful in clinical practice.
Acknowledgements

Firstly, I would like to thank my supervisor, Prof. Mark Stringer, for his patient guidance and support through this project. I am so blessed to have spent this time under your tutelage.

Thanks to Dr. Ali Mirjalili, who has been a great colleague and friend. It has been a pleasure to work with you.

Thanks to Gerry Hill of the University of Otago Department of Surgery, for her expertise in vascular ultrasonography and her Irish sense of humour.

Thanks to Prof. Tim Buckenham and Ms. Rona Buttimore (research nurse) of the University of Otago Christchurch School of Medicine, for providing the CT scans for the CT reappraisal of central venous surface markings.

Thanks to Prof. Peter Herbison and Ms. Sophia Leon de la Barra, for their biostatistical advice.

Thanks to Mr. Robbie McPhee for his artistic talent in drawing Figure 4.

Finally, thanks to my parents, family and friends for their love, support and prayers in times of stress, and to my flatmates, for making this year so great.
Contents

Abstract ........................................................................................................................... ii
Acknowledgements ....................................................................................................... iv
Contents.......................................................................................................................... v
List of Tables .................................................................................................................. ix
List of Figures ............................................................................................................... x
List of Abbreviations ..................................................................................................... xi
1 Introduction ................................................................................................................. 1
  1.1 Overview .............................................................................................................. 1
  1.2 History .................................................................................................................. 1
  1.3 Sources of knowledge of surface anatomy ......................................................... 4
  1.4 Clinical importance and the role of imaging techniques .............................. 5
    1.4.1 CT ............................................................................................................... 5
    1.4.2 MRI ............................................................................................................ 7
    1.4.3 Ultrasound ................................................................................................... 8
    1.4.4 Cost and availability ................................................................................... 10
    1.4.5 The value of physical examination ............................................................... 10
  1.5 Central venous surface anatomy: a critical reappraisal ............................ 11
2 Surface anatomy reporting in contemporary anatomy texts: uniformity and inconsistency ......................................................... 13
  2.1 Introduction ........................................................................................................... 13
  2.2 Methods ............................................................................................................... 14
  2.3 Results .................................................................................................................... 14
    2.3.1 Thorax .......................................................................................................... 14
      2.3.1.1 Sternal angle .......................................................................................... 14
      2.3.1.2 Xiphisternal joint ............................................................................... 17
      2.3.1.3 Cardiac anatomy .................................................................................. 17
      2.3.1.4 Central venous anatomy .................................................................... 18
      2.3.1.5 Pleura, Lungs and Diaphragm .............................................................. 18
      2.3.1.6 Breast and nipple ............................................................................... 19
2.3.2 Abdomen ................................................................. 20
  2.3.2.1 Subcostal plane .................................................. 20
  2.3.2.2 Supracristal plane ............................................. 20
  2.3.2.3 Bifurcation of abdominal aorta ............................ 20
  2.3.2.4 Formation of inferior vena cava ............................ 21
  2.3.2.5 Umbilicus ....................................................... 21
  2.3.2.6 Kidneys ........................................................ 21
  2.3.2.7 Major openings in and behind the diaphragm .......... 22
  2.3.2.8 Arteries to the gut and kidneys .......................... 22
  2.3.3 Lower limb ....................................................... 22
  2.3.3.1 Femoral artery in the groin ............................... 22
  2.3.3.2 Great saphenous vein ....................................... 23
  2.3.4 Neck ............................................................... 23
  2.3.4.1 Bifurcation of common carotid artery .................... 23
  2.3.4.2 Plane of C6 ................................................ 23
  2.4 Discussion .............................................................. 24
  2.4.1 Evidence based reappraisal .................................. 26
    2.4.1.1 Supracristal plane ........................................ 26
    2.4.1.2 Renal dimensions ......................................... 27
    2.4.1.3 Femoral artery in the groin ............................ 27
    2.4.1.4 Superior vena cava/right atrial (SVC/RA) junction .. 28
  2.5 Conclusions .......................................................... 29

3 Reappraising central venous surface anatomy with computerised tomography ........................................ 30
  3.1 Introduction .......................................................... 30
  3.2 Methods .............................................................. 32
    3.2.1 Statistical analyses .......................................... 40
    3.2.2 Reliability .................................................... 45
    3.2.3 Ethical considerations ....................................... 45
  3.3 Results ............................................................... 45
    3.3.1 Reliability .................................................... 51
      3.3.1.1 Intra-observer repeatability .......................... 51
      3.3.1.2 Inter-observer reproducibility .................... 52
  3.4 Discussion ............................................................ 53
    3.4.1 Repeatability and reproducibility ........................ 54
    3.4.2 Previous studies ............................................. 54
    3.4.3 Merits and limitations of the present study ........... 56
    3.4.4 Future directions ........................................... 59
  3.5 Conclusion .......................................................... 59

4 Defining the surface anatomy of the subclavian vein by ultrasound .................................................... 60
  4.1 Introduction .......................................................... 60
6.5 Conclusions ......................................................................................................................... 99
References .................................................................................................................................. 100
APPENDIX A .............................................................................................................................. 109
APPENDIX B .............................................................................................................................. 115
APPENDIX C .............................................................................................................................. 120
APPENDIX D .............................................................................................................................. 125
APPENDIX E .............................................................................................................................. 135
APPENDIX F .............................................................................................................................. 139
APPENDIX G .................................................................................................................................. 141
List of Tables

Table 1. Surface anatomical structures and reviewed texts..................15
Table 2. Details of participants..............................................32
Table 3. Location of the formation of the brachiocephalic vein relative to
the ipsilateral sternoclavicular joint.........................................46
Table 4. Measurements to the sternal angle, midline and midclavicular line
................................................................................................46
Table 5. Surface markings in relation to costal cartilages and vertebral
levels .....................................................................................47
Table 6. P values of associations with age, gender and BMI.................48
Table 7. Azygos vein and cardiac apex: measurements to sternal angle,
midline and midclavicular line related to age, gender and BMI.........49
Table 8. Surface markings in relation to costal cartilages and vertebral
levels, according to age, gender and BMI..................................50
Table 9. ICC values for continuous data......................................51
Table 10. Kappa and weighted kappa values for ordinal data............51
Table 11. ICC values for continuous data.....................................52
Table 12. Kappa and weighted kappa values for ordinal data............52
Table 13. Details of participants..................................................62
Table 14. Measurements characterising the relationship of the SCV to the
clavicle, and changes after passive shoulder retraction ..................69
Table 15. Significance of associations with age, gender and BMI........70
Table 16. Measurements stratified by age, gender and BMI.............71
Table 17. Repeatability statistics................................................74
Table 18. Published recommended points of needle entry for infraclavicular
SCV access.................................................................80
List of Figures

Figure 1. Figure from Waterston (1931) showing thoracic and some visceral abdominal surface anatomy ........................................ 3
Figure 2. Transverse E12 cadaveric section with computerised tomographic and magnetic resonance images at an equivalent level ............ 6
Figure 3. Duplex ultrasound image showing the author’s abdominal aorta in longitudinal section, below the level of the kidneys ................ 9
Figure 4. Common projectional surface markings of the human body ...... 16
Figure 5. Modified Cobb method for determining angle of kyphosis .... 33
Figure 6. Identification of the first thoracic vertebra ................................ 36
Figure 7. Location of the formation of the brachiocephalic veins .......... 37
Figure 8. Location of the formation of the superior vena cava .......... 38
Figure 9. Location of the superior vena cava/right atrial junction ........ 39
Figure 10. Location of the union of the azygos vein and superior vena cava ................................................................. 41
Figure 11. Location of the cardiac apex ........................................ 42
Figure 12. Determining the position of the midclavicular line and the cardiac apex relative to it .................................................. 43
Figure 13. Calculation of the theoretical shift of the midclavicular line with changing position of the clavicle ........................................ 58
Figure 14. A participant undergoing an ultrasound scan of the right SCV.64
Figure 15. Typical B-mode ultrasound image of the left subclavian vein ..65
Figure 16. Marks on the skin used to take measurements and their corresponding structures ...................................................... 66
Figure 17. Distribution of distances to the mid-jugular notch (cm) with and without passive shoulder retraction ................................... 72
Figure 18. Typical ultrasound image through an intercostal space, just lateral to the sternum .......................................................... 86
Figure 19. Duplex image of cardiac chambers visible through the liver ... 86
Figure 20. Waves passing across a specular reflector and the formula for the amplitude reflection coefficient ............................. 88
Figure 21. Duplex image demonstrating reverberation artefact .......... 90
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCV</td>
<td>Brachiocephalic vein</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>CC</td>
<td>Costal cartilage</td>
</tr>
<tr>
<td>CT</td>
<td>Computerised tomography</td>
</tr>
<tr>
<td>ICS</td>
<td>Intercostal space</td>
</tr>
<tr>
<td>MCL</td>
<td>Midclavicular line</td>
</tr>
<tr>
<td>MRI</td>
<td>Magnetic resonance imaging</td>
</tr>
<tr>
<td>NZD</td>
<td>New Zealand dollars</td>
</tr>
<tr>
<td>SCV</td>
<td>Subclavian vein</td>
</tr>
<tr>
<td>SVC</td>
<td>Superior vena cava</td>
</tr>
<tr>
<td>SVC/RA</td>
<td>Superior vena cava/right atrial</td>
</tr>
<tr>
<td>TOE</td>
<td>Transoesophageal echocardiography</td>
</tr>
</tbody>
</table>
1 Introduction

1.1 Overview

Human surface anatomy is the relation of subcutaneous and deeper structures to the external surface of the human body. It can be divided into two main categories: palpable, and projectional. Palpable surface anatomy describes the superficial structures of the body just under the skin that can be identified by palpation in normal, healthy individuals, such as the ribs, sternal angle, and anterior superior iliac spine. In lean individuals, these structures may even be visible from the overlying skin contours. In contrast, projectional surface anatomy describes the surface projection of deeper structures (that are often not palpable) in relation to palpable landmarks; examples include the cardiac borders, central venous anatomy, and the inferior borders of the pleura and lungs. This thesis will focus primarily on thoracic projectional surface anatomy which, though deeply entrenched in the compendia of medical and anatomical knowledge, has been largely neglected as a matter of research until recent years. As such, its accuracy and reliability may be questionable, even though it is used as a daily yardstick in clinical practice and has become a core feature of almost all clinical anatomical reference texts.

1.2 History

Projectional surface anatomy has been a part of clinical practice and
anatomy teaching for many years (Fig. 1). Its importance was recognised at least as early as 1896 (Windle 1896), but some elements of surface anatomy were even present in the first edition of *Gray’s Anatomy* (Gray 1858) such as the lower border of the cricoid cartilage, the kidneys and the femoral artery in the groin. These surface anatomy landmarks are remarkably similar to many of the surface markings in use today, indicating how little surface anatomy has changed over time. These similarities may indicate either a lack of research on this subject by anatomists, causing projectional surface anatomy to become anatomical dogma devoid of an evidence base, or that surface anatomy is indeed reliable and, once established, has not changed with the advent of modern imaging techniques. The latter may be true for some surface markings; current evidence shows that Henry Gray was correct in siting the femoral artery at the mid-inguinal point (see chapter 2). Likewise, the surface marking for the aortic bifurcation remains the same, and that for the formation of the inferior vena cava has changed only very slightly in the light of modern imaging in later editions of this famous text (Kornreich et al. 1998; Pirró et al. 2005; Standring 2008).

Yet for most projectional surface anatomy, no such evidence base exists. Clinically important markings like that for the junction of the superior vena cava and right atrium (SVC/RA junction) still remain relatively unexplored by anatomists. Only one study has investigated the third right costal cartilage as a landmark for this junction in living individuals (Hsu et al. 2007), even though most textbooks promote this site without question. The issues of accuracy and evidence base must be dealt with if surface anatomy is to retain its credibility and clinical utility.
Figure 1. Figure from Waterston (1931) showing thoracic and some visceral abdominal surface anatomy.
1.3 Sources of knowledge of surface anatomy

Our understanding of projectional surface anatomy is largely derived from cadaver studies, limited by distortion from embalming, co-morbidity, fixed body position, and age-related changes. Cadavers are generally elderly so variation in surface anatomy with age cannot be examined. They are embalmed and stored supine, and phase of respiration cannot be investigated; both posture and respiratory excursion of the diaphragm have a profound effect on the position of the abdominal and thoracic viscera. Moreover, cadaver lungs are filled with fluid, and changes in total body fluid and its distribution as a result of death and embalming may distort anatomy. Finally, study samples of cadavers are generally more limited than modern in vivo radiological studies. While the foundations of gross anatomy were in cadaver dissection, it is an inadequate technique for the study of surface anatomy in the living.

Radiographic investigations have the advantage of studying living individuals. However, radiographs show little soft tissue detail, so they are useful only in investigations of skeletal and some larger visceral surface anatomy. Their scope may be expanded with the introduction of contrast media, allowing imaging of structures such as the ureters and the vasculature, but this technique has limitations of its own. Hypersensitivity reactions may be serious (Brockow and Ring 2010), and patients with renal impairment are at increased risk of contrast-media-induced kidney injury (Thomsen and Morcos 2009).

In recent years, with the advent of modern radiological techniques such as computerised tomography (CT) and magnetic resonance imaging (MRI), investigators have begun to show more interest in living surface anatomy.
However, many surface markings remain unexamined, and there is still need for a widespread critical reappraisal of human projectional surface anatomy.

1.4 Clinical importance and the role of imaging techniques

It may be argued that surface anatomy has been superseded in clinical practice by sophisticated imaging techniques like CT, MRI and ultrasound. However, each of these has disadvantages including cost, availability and radiation exposure, meaning that projectional surface anatomy is still used daily in the clinic. Further, despite these widely available imaging tools in modern healthcare systems, clinical examination remains a fundamental aspect of the practice of medicine throughout the world. It is useful to consider the relative strengths and weaknesses of each of these three key imaging modalities since this is relevant to their application to researching human surface anatomy.

1.4.1 CT

Developed by Sir Godfrey Hounsfield and Dr. James Ambrose in the late 1960s and early 70s, X-ray computed tomography (then known as computed axial tomography) was lauded as the “greatest advance in radiologic medicine since the discovery of the X-ray” (Petrik et al. 2006; Goodman 2010) (Fig. 2B). The first scan of a human head took place in 1971, with subsequent rapid development leading to the advent of the chest CT. Today, 75 million CTs are performed annually in the United States and 93 million worldwide (Petrik et al. 2006; Smith-Bindman, 2010), with chest scans accounting for around 30% of these (Goodman, 2010).

While CT scanners are virtually ubiquitous in modern hospitals, concerns
Figure 2. A. Transverse E12 cadaveric section at approximately T6 level. B. Axial computerised tomographic image at a similar level (courtesy of Prof. Tim Buckenham, University of Otago). C. Axial T2 weighted magnetic resonance image (MRI) at a similar level. This MRI is not completely normal, showing bilateral pleural effusions (Osirix Imaging Software DICOM sample image datasets, © Antoine Rosset, 2003-2010, California, USA, http://pubimage.hcuge.ch:8080/DATA/PNEUMATIX.zip, last accessed 10th January 2011).
for patient safety have been raised due to exposure to ionising radiation. Dosage may be up to 500 times greater than a plain radiograph (Smith-Bindman 2010), and while no completed studies have focused specifically on the effect of radiation from CT, there is clear evidence that equivalent doses are mildly carcinogenic (Brenner and Hall 2007). One review estimates that in the United States, radiation exposure from CT may be responsible for up to 2% of all cancer. Moreover, an estimated one-third of all paediatric CTs may be unnecessary even though the risk of carcinogenesis is greatest in children (Brenner and Hall 2007).

In most instances, the potential benefits of CT outweigh the minimal risks to the individual. However, these risks become more apparent at a population level. Radiation exposure must therefore be minimised, which may mean reducing the dosage from each scan and the number of scans performed (Smith-Bindman 2010). CT cannot be used on every patient that enters the hospital; it is not safe enough for unrestricted use. It will not therefore eliminate the need for surface anatomy but can be used selectively as a valuable research tool.

1.4.2 MRI

MRI uses non-ionising radiofrequency signals in a strong magnetic field to create images of the body (Benavente-Fernández et al. 2010) (Fig. 2C). It was developed in the UK in the 1970s by a group of Scottish physicists and established as a diagnostic tool in 1980 (Smith 2006). MRI provides greater soft tissue definition than CT and is the gold standard neuroimaging technique (Brenner and Hall 2007; Bradley 2008; Benavente-Fernández et al. 2010).

The absence of ionising radiation makes MRI a much safer modality than
X-ray CT. Some patients report transient symptoms such as vertigo or a metallic taste when moving in and out of the magnet, however there is no evidence of long-term harm even in magnetic fields of up to 8T (Chakares and de Vocht 2005).

However, MRI does pose some serious risks to a few individuals. The strength of the magnets makes the presence of metallic foreign bodies like surgical clips or intraocular fragments highly hazardous, so radiographic or CT screening before MRI scanning is employed in some institutions. Metal objects in the room may become missiles; one author reported facial injuries from a flying oxygen tank (Boutin et al. 1994). Also, radiofrequency stimulation may cause localised burns, and claustrophobia may present an obstacle for some patients (Chakares and de Vocht 2005). Nonetheless, these risks may be minimised with care, making MRI a generally safe medical imaging technique.

1.4.3 Ultrasound

B-Mode (“brightness mode”) is the most common form of ultrasound imaging, where sound waves are projected into the tissues and an image constructed based on their echoes (Fig. 3). The potential for using sound waves for medical imaging was recognised as early as the 1930s by Karl and Friederich Dussik. The technology was developed in the 1940s and 50s primarily by radiologist Douglass Howry and surgeon John Julian Wild in the United States, with advances from numerous other investigators, and real-time B-mode ultrasound became commercially available in the mid 1960s with the advent of the Siemens Vidoson (Newman and Rozycki 1998).

Risk of tissue damage from ultrasound is very low, with certain
Figure 3. Duplex ultrasound image showing the author’s abdominal aorta in longitudinal section, below the level of the kidneys.
exceptions: if contrast agent is used, the operator must exercise caution so as to avoid formation of gas bubbles in the tissue. Care must also be taken with transcranial doppler to avoid neural damage from localised production of heat (Duck 2008). Aside from these, ultrasound is considered very safe and in trained hands, these risks can be minimised. Its safety is underlined by its widespread use in obstetrics.

Ultrasound does, however, suffer significant limitations. Image quality decreases when visualising deep structures and the sound waves lose energy passing through body fat, making imaging difficult in obese subjects. Also, bone and air act as barriers to the ultrasound signal, which can be problematic in the abdomen and especially in the thorax. Ultrasound may prove inadequate in these situations, which limits its use in the clinic.

1.4.4 Cost and availability

Cost and availability of the necessary equipment means that access to modern imaging techniques is limited in many parts of the world. A standard ultrasound system will cost between $70,000 and $230,000 New Zealand Dollars (NZD), a CT scanner between $500,000 and $2.4m NZD and an MRI system up to $4m NZD. This cost is often too great for many third world hospitals and even rural clinics in wealthy nations, and in many cases the nearest facility equipped with these may be hours away. This is particularly the case with CT and MRI, but the cost of ultrasound equipment may still be prohibitive. In this case, it is not possible to rely on sophisticated medical imaging, and the surface anatomy implicit to physical examination becomes all the more important.

1.4.5 The value of physical examination

Modern imaging techniques are an invaluable aid to diagnosis and
intervention. Yet physical examination, and consequently surface anatomy which forms part of this process, remains vital to safe clinical practice. How can we be good physicians if the patient is reduced to an image on a screen? Many clinical signs cannot be elicited with imaging studies, and patients may be spared unnecessary and potentially harmful investigations if differential diagnoses can be eliminated at the bedside. Importantly, it also helps to build the doctor patient relationship (Verghese and Horwitz 2009).

Given the undeniable value of physical examination, it is probable that it will never be completely superseded by medical imaging. It is thus important that our knowledge of surface anatomy be as accurate as possible.

1.5 Central venous surface anatomy: a critical reappraisal

Considering its origins and the need for accuracy, the consistency and reliability of surface anatomy should be questioned. One indicator of consistency (and possibly accuracy) is the reporting of surface anatomy in major anatomical reference texts. This is examined in chapter 2 of this thesis, which discusses the reporting of surface anatomy relevant to cardiorespiratory medicine and cardiothoracic surgery in thirteen popular, widely used anatomical reference and clinical examination texts. Selected landmarks are then reappraised in the light of recent literature.

One area of particular interest arising from this critical review was the surface anatomy of the central veins: specifically, the subclavian vein and its junction with the internal jugular vein; the formation of the superior vena cava by the right and left brachiocephalic veins and its union with the azygos vein; and the junction of the superior vena cava with the right atrium of the heart. These markings are important in the context of central venous
catheterisation. When modern imaging is unavailable, and more often in emergency situations, needles may be inserted into central veins and catheter tips positioned without guidance. Therefore, the clinician requires an accurate understanding of central venous surface anatomy in order to minimise risk and optimise patient outcomes. This prompted further investigation of the central veins using CT and ultrasound, with the aim of establishing reliable, evidence based surface markings. These data are presented in chapters 3 and 4, respectively.

Chapter 5 discusses the difficulties in attempting to image the SVC/RA junction with ultrasound. This was an unsuccessful attempt to establish an evidence based surface marking using ultrasound by which catheter tips could be positioned.

Finally, chapter 6 reviews the findings and draws conclusions.

A critical reappraisal of projectional surface anatomy is long overdue. By focusing on thoracic surface anatomy and the surface projections of the central veins in particular, this thesis should contribute towards bringing surface anatomy into the modern evidence based era.
2 Surface anatomy reporting in contemporary anatomy texts: uniformity and inconsistency

2.1 Introduction

Surface anatomy is a core component of human anatomy essential to safe clinical practice. Our current understanding of the topic is largely derived from cadaver studies, with all the limitations of distortion from embalming, positioning, age, and co-morbidity, and from radiographic investigations. In the last two decades, numerous studies have critically evaluated traditional surface landmarks in living subjects using modern imaging techniques such as computerised tomography (Chukwuemeka et al. 1997; Glodny et al. 2009), magnetic resonance imaging (MRI) (Soleiman et al. 2005; Cheong et al. 2007), and ultrasound scanning (Emamian et al. 1993).

The primary aim of this study was to determine the extent to which modern clinical anatomy texts are consistent in their reporting of common surface markings. In addition, we sought to determine whether these landmarks are included in standard undergraduate texts of clinical examination and, if so, whether they too are reported consistently. Finally, selected surface markings were reviewed for accuracy in the light of current literature.
2.2 Methods

Thirteen popular reference texts in widespread use were analysed in detail: one clinical and anatomical reference text (A1); seven clinical anatomy texts (CA1-7); two surface anatomy texts (SA1-2); and three clinical examination texts (E1-3) (Table 1). All texts were searched for descriptions of adult surface anatomy (Fig. 4) relating to the structures listed in Table 1. Descriptions were transcribed verbatim into a spreadsheet (Microsoft ® Excel ® 2008 for Mac version 12.2.4, Microsoft Corporation, Redmond, WA, USA) and most entries were checked independently by two researchers (Samuel Hale and Dr. Ali Mirjalili) to ensure completeness and accuracy. These data were then reviewed, summarised and assessed for consistency by two investigators (Samuel Hale and Prof. Mark Stringer). Conventional shorthand is used to express vertebral levels i.e. C = cervical, T = thoracic, L = lumbar, and S = sacral, with L4/5 indicating the intervertebral disc between the fourth and fifth lumbar vertebrae.

In the original review (Appendix A), data were collected for surface markings around the body. However, as this thesis focuses on central venous surface markings, this chapter has been restricted to those markings relevant to cardiorespiratory medicine and cardiothoracic surgery.

2.3 Results

2.3.1 Thorax

2.3.1.1 Sternal angle

The horizontal plane of the sternal angle is level with the second costal cartilage anteriorly and generally stated to intersect the junction of T4/5 or
<table>
<thead>
<tr>
<th>Surface anatomical structure</th>
<th>Reference texts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thorax</strong></td>
<td>Clinical and Anatomical Reference</td>
</tr>
<tr>
<td></td>
<td>A1 Standring (2008)</td>
</tr>
<tr>
<td></td>
<td>Clinical Anatomy</td>
</tr>
<tr>
<td></td>
<td>CA1 Moore <em>et al.</em> (2010)</td>
</tr>
<tr>
<td></td>
<td>CA2 Drake <em>et al.</em> (2010)</td>
</tr>
<tr>
<td></td>
<td>CA3 Sinnatamby (2006)</td>
</tr>
<tr>
<td></td>
<td>CA4 McMinn (1998)</td>
</tr>
<tr>
<td></td>
<td>CA5 Rosse and Gaddum-Rosse (1997)</td>
</tr>
<tr>
<td></td>
<td>CA6 Ellis and Mahadevan (2010)</td>
</tr>
<tr>
<td></td>
<td>CA7 Abrahams <em>et al.</em> (2005)</td>
</tr>
<tr>
<td><strong>Abdomen</strong></td>
<td>Surface Anatomy</td>
</tr>
<tr>
<td></td>
<td>SA1 Lumley (2008)</td>
</tr>
<tr>
<td></td>
<td>SA2 Field and Hutchinson (2005)</td>
</tr>
<tr>
<td><strong>Lower Limb</strong></td>
<td>Clinical Examination</td>
</tr>
<tr>
<td></td>
<td>E1 Bickley and Szilagyi (2008)</td>
</tr>
<tr>
<td></td>
<td>E2 Douglas <em>et al.</em> (2009)</td>
</tr>
<tr>
<td></td>
<td>E3 Talley and O’Connor (2009)</td>
</tr>
<tr>
<td><strong>Neck</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4. Common projectional surface markings of the human body.
the lower border of T4 posteriorly. Most clinical anatomy texts also mention that this plane marks the division of the superior and inferior mediastinum, the bifurcation of the trachea, the origin and termination of the aortic arch, the level at which the azygos vein enters the superior vena cava, the approximate level at which the thoracic duct crosses to the left side of the posterior mediastinum, the superior limit of the pericardium, and the site at which the right and left parietal pleura come into contact anteriorly.

The sternal angle receives little attention in the clinical examination texts which simply state that it is level with the second costal cartilage anteriorly; only one of these texts mentions the tracheal bifurcation and arch of aorta (E1). Some inconsistencies are apparent within and between anatomy texts. A1 states that the level of the tracheal bifurcation is at the upper border of T5 in one section and T4 in another. Only a few texts comment on variation with respiration (A1, CA1, CA3-6), posture and build (CA1, CA5). One clinical anatomy text describes the pulmonary arteries originating at the level of the sternal angle (CA1) and another at an even higher plane (CA5).

2.3.1.2 Xiphisternal joint
The vertebral level of the xiphisternal joint is generally agreed to be about T9 but minor variations exist e.g. lower border of T8 (CA2-4), T8/9 (CA1) and T10 (CA5). A few texts do not give a vertebral level (SA2, CA7, E1-3).

2.3.1.3 Cardiac anatomy
The heart borders are well described in A1 which documents their general position as clockwise from the left second costal cartilage 1 cm from the sternal edge, to the apex of the heart in the left fifth intercostal space near the midclavicular line, to the right sixth costal cartilage 1-2 cm lateral to the sternal edge, and to the right third costal cartilage. This text
also emphasises variation with age, sex, stature, build (obesity), respiration, and posture. Only minor differences are found in other texts. For example, CA2 states that the upper left border of the heart lies behind the left second intercostal space. However, there are omissions: two texts document only one of these landmarks (CA5, CA7), two only show approximate borders in a diagram (E2, E3) and one fails to mention the position of the apex (CA7).

Sites of auscultation for optimum detection of cardiac valve murmurs are mostly consistent but are omitted in two texts (CA6, SA2). Tricuspid valve murmurs are generally reported to be heard best in the fifth intercostal space at the lower left sternal edge but some texts suggest that these murmurs are heard best over the lower sternum in the midline (CA3-5) or over the right fourth costal cartilage (SA1).

2.3.1.4 Central venous anatomy

Most anatomy texts refer to the formation of the brachiocephalic veins behind the sternoclavicular joints or sternal end of the clavicles, their union to form the superior vena cava posterior to the right first costal cartilage, and the entry of the superior vena cava into the right atrium behind the right third costal cartilage. Notable discrepancies are the formation of the superior vena cava behind the right first rib (CA5) or at the level of the sternal angle (SA1). These landmarks are not documented in the clinical examination texts.

2.3.1.5 Pleura, Lungs and Diaphragm

The surface markings of the pleura and lungs vary little between anatomical texts but are surprisingly neglected in the clinical examination texts, where, at most, they are indicated by a rough diagram. The dome of cervical pleura and apex of lung are typically described as 2.5 cm above the medial third of the clavicle but some texts state that this point is the junction
of the medial and middle thirds of the clavicle (CA3, CA6). Two texts are inconsistent within themselves: A1 reports both of these landmarks, and CA7 mentions the medial third of the clavicle and the mid-clavicle in different sections. Only a few texts emphasise that the pleura extends just below the 12th rib at its medial extremity (CA3-7).

One major inconsistency is the level of the anterior projection of the domes of the diaphragm after maximum expiration. The right dome is variably stated to be level with the fourth costal cartilage or rib (CA2, SA2), fourth intercostal space (CA3, CA4) or fifth rib (CA1) with the left dome half a rib space below, i.e. fourth intercostal space, fifth rib or fifth intercostal space. CA1 also places the domes at the fourth intercostal space bilaterally but with the right dome higher than the left. Other texts give the fourth costal cartilage or intercostal space on the right and one rib space lower on the left (i.e. the fifth costal cartilage or fifth intercostal space) (A1, CA5, SA1). Some texts offer no surface marking (CA6, CA7, E1, E3).

Variation in the position of the dome of the diaphragm with respiration, posture, and build is mentioned in only a few texts (A1, CA1-5, SA2).

2.3.1.6 Breast and nipple

The female breast is relatively consistent throughout the texts. It is generally stated to extend from the second or third to the sixth rib, and from the sternal edge to the midaxillary line with an axillary tail (A1, CA1-3, CA7). Minor variations include near or at the midline medially (CA4, CA5); the seventh rib inferiorly and anterior axillary wall laterally (SA1); and the clavicle or second rib superiorly (E1). CA6 omitted a lateral marking and the axillary tail, and three texts ignore the female breast entirely (SA2, E2, E3).
Where markings are given, the male nipple is consistently stated as lying in the fourth intercostal space, at or lateral to the MCL (A1, CA1, CA5, CA6, SA1). Two texts give no mention of the MCL (CA3, CA4), and others omit the male nipple entirely (CA7, SA2, E1-3).

2.3.2 Abdomen

2.3.2.1 Subcostal plane

This horizontal plane joining the lowest points of the costal margins is typically described as intersecting the body of L3 and the tenth costal cartilage with the third part of the duodenum and the origin of the inferior mesenteric artery at this level (A1, CA6). Some anatomy texts do not specify a vertebral level (CA1, CA3, CA4), and one surface anatomy text (SA2) and all three clinical examination texts do not mention this plane.

2.3.2.2 Supracristal plane

This horizontal plane between the most superior points of the iliac crests is reported to pass through the body of L4 or the L4/5 intervertebral disc in most texts. It is also referred to as the “intercristal” line (SA1) or, in one text (CA6), as the “supracristal line” and the “transcristal plane.” This landmark is only referred to in one clinical examination text (E1).

2.3.2.3 Bifurcation of abdominal aorta

Most texts state that the abdominal aorta bifurcates at the lower border of L4 just to the left of the midline; this is in the supracristal plane, about 2 cm below and to the left of the umbilicus. One text erroneously refers to this as the transtubercular plane in one section (though it correctly states supracristal in another) (A1), whereas others place the bifurcation at the level of the umbilicus (SA1, E2) or 2.5 cm below the supracristal plane (SA2).
2.3.2.4 Formation of inferior vena cava

All but one anatomy text agree that the inferior vena cava is formed slightly to the right (~2.5cm) of the midline anterior to L5, further qualified as the transtubercular plane in some texts (A1, CA3-5). One aberrant text states L4 (SA2). The clinical examination texts do not describe a surface marking.

2.3.2.5 Umbilicus

The umbilicus is an inconstant landmark approximately in line with L3/4 in lean young adults but at a lower level in the obese. One text (CA5) documents the umbilicus at L4 in the supracristal plane. Several texts do not mention the level of the umbilicus (CA7, SA2, E1-3).

2.3.2.6 Kidneys

The most comprehensive description of the surface anatomy of the kidneys is found in A1, which describes the hila lying approximately in the transpyloric plane about 5 cm from the midline, with the right kidney 1.25 cm lower than the left. Both kidneys lie obliquely between the upper border of T12 and L3, the upper pole of the right is anterior to the 12th rib whereas that on the left lies anterior to the 11th and 12th ribs. Position varies with posture and respiration. Renal length is given as 11 cm, and width as both 4.5 and 6 cm in different sections.

Most clinical anatomy texts largely concur with this description, but there are minor inconsistencies. For example, CA6 places the right kidney 2.5 cm lower than the left and, in another section, 12 mm lower; CA1 places the superior poles of both kidneys deep to the 11th and 12th ribs; and two texts state that the kidneys are 10 cm long (CA1, CA7). Of the three clinical examination texts, two are broadly in agreement, whereas E1 simply states that the upper pole of both kidneys is related to the 11th and 12th ribs.
2.3.2.7 Major openings in and behind the diaphragm

These are mostly given as T8 behind the right sixth costal cartilage (inferior vena cava), T10 just to the left of the midline (oesophagus), and T12 in the midline (aorta). There are minor inconsistencies: A1 cites both T12 and T12/L1 to the left of the midline for the aorta and A1 and CA1 both give T8 and T8/9 for the inferior vena cava. These landmarks are absent from the clinical examination texts.

2.3.2.8 Arteries to the gut and kidneys

In anatomy texts, the origin of the coeliac trunk, superior mesenteric artery, and inferior mesenteric artery are consistently given as T12 (or upper border L1 in CA2), L1 or L1/2, and L3, respectively. A1 states that the origin of the superior mesenteric artery is at the level of L1/2 and later that it ‘usually lies above the level of the transpyloric plane’ (given as lower border of L1). Clinical examination texts do not detail these levels.

The renal arteries, when single, are described as arising from the abdominal aorta at L1/2 or L2 (A1, CA2, and CA5 also emphasising variability).

2.3.3 Lower limb

2.3.3.1 Femoral artery in the groin

Most texts state that the femoral artery is located at the mid-inguinal point, i.e. midway between the anterior superior iliac spine and the pubic symphysis (A1, CA3-7, SA1, E1, E2). However, two clinical anatomy texts (CA1, CA2) refer not only to this landmark but also to the midpoint of the inguinal ligament. One clinical examination text (E3) describes the femoral pulse as being “...situated below the inguinal ligament, one-third of the way up from the pubic tubercle...”
2.3.3.2 Great saphenous vein

The site of the saphenous opening (saphenofemoral junction) is confusing. It is stated in CA3 and CA4 to be 3 or 3.5 cm “below and lateral to the pubic tubercle.” However, does this mean 3 or 3.5 cm below and 3 or 3.5 cm lateral as indicated by CA1 and E2 or is a diagonal distance envisaged? Other texts, such as A1, are more specific, stating 3 cm lateral to a point just distal to the pubic tubercle. Some texts use the femoral pulse as a guide, e.g. 2.5 cm below the inguinal ligament just medial to the femoral pulse (CA6, SA2). Notable exceptions are CA7 and SA1, which place the opening 3–4 cm inferior and just lateral to the pubic tubercle. Two texts simply give the general vicinity of the opening as just inferior to the medial end of the inguinal ligament (CA2, CA5). There is a consensus that the great saphenous vein lies immediately anterior to the medial malleolus at the ankle although this surface marking is omitted in two texts (SA1, E3).

2.3.4 Neck

2.3.4.1 Bifurcation of common carotid artery

This surface landmark is not included in the clinical examination texts, but the anatomy texts all agree on the upper border of the thyroid cartilage at C3/4 (A1, CA2) or C4 (CA1, CA3, CA4, CA6, CA7). CA5 gives no vertebral level. Three texts highlight variability (A1, CA3, CA4).

2.3.4.2 Plane of C6

There is a consensus that C6 corresponds to the level of the cricoid cartilage (specifically, its lower border [CA2, CA6, SA1]) and that this marks the transition from pharynx to oesophagus, larynx to trachea, and the position of the middle cervical ganglion. Many texts point out that the vertebral artery enters the foramen transversarium and that the inferior thyroid artery can be located at this level (CA1, CA3, CA4, CA6). The C6
landmark is not mentioned in the clinical examination texts.

2.4 Discussion

All of the texts reviewed in this study have their individual strengths and particular target readership, but they nevertheless constitute classical reference sources for clinical anatomy. The purpose of this study was not to criticise these successful books, but to highlight inconsistencies in standard surface anatomy and the need for an evidence based reappraisal of this topic. We attempted to minimise errors by using two researchers to independently review data at two key stages of the study, i.e. data entry and data analysis.

This study demonstrates four important points about surface anatomy as presented in popular contemporary texts of clinical and surface anatomy and clinical examination. First, there are numerous inconsistencies in clinically important surface markings. These include major discrepancies (e.g., the femoral artery in the groin, the saphenofemoral junction, and the anterior projection of the dome of the diaphragm) and minor but potentially significant inconsistencies (e.g., the bifurcation of the abdominal aorta, renal dimensions and surface anatomy, and the level of the tracheal bifurcation). Surprisingly, there are also inconsistencies within texts, some of which may be related to their multi-author nature. Second, there is a consensus on many surface markings such as the supracristal plane, the formation of the inferior vena cava, structures at the level of C6, and the female breast. Third, few texts mention variation in surface anatomy related to age, sex, body mass (particularly obesity), posture, respiration, and ethnicity. *Gray’s Anatomy* (Standring 2008) is the most comprehensive in this respect. Finally, the three standard clinical examination texts included in this review contain comparatively little surface anatomy and omit aspects
such as central venous anatomy, structures at the level of the sternal angle, bifurcation of the common carotid artery, and the relevance of C6. Some structures, such as the cardiac borders (E2, E3) and surface markings of the pleura and lungs (E1-3) are given only approximately in a diagram.

Is surface anatomy neglected in modern texts of clinical examination because it has limited clinical utility or has been superseded by modern non-invasive imaging techniques? This may be particularly true for the deeper projectional surface anatomy of thoracic and abdominal viscera exemplified by the sternal angle and subcostal plane. However, clinical examination, which involves knowledge of surface anatomy, has not been supplanted by technology (Verghese and Horwitz 2009). Access to imaging technology is variable, and a structure like the femoral artery needs to be located accurately, reliably, and sometimes promptly in everyday clinical practice. In addition, surface anatomy is not just about clinical examination but may provide convenient reference points for the surgeon (e.g. siting incisions) and radiologist (e.g. the approximate vertebral level of an artery) and is almost certainly of value in helping students learn human anatomy as indicated by the success of body painting as a learning tool (McMenamin 2008).

Given the importance of surface anatomy, educational resources need to be more consistent. This, in turn, means using the best available evidence and greater acknowledgement of the potential for variation. In recent years, numerous studies have used modern imaging techniques in living subjects to challenge the validity of traditional surface landmarks based on cadaver dissections and conventional radiography. Incorporating these into modern surface anatomy will inevitably demand a balance between simplification, which assists learning and clinical application, and the need for precision.
The following examples of surface landmarks reviewed in this study illustrate different aspects of the contribution of an evidence based reappraisal.

2.4.1 Evidence based reappraisal

2.4.1.1 Supracristal plane

The supracristal or intercristal plane is frequently used as a guide for lumbar puncture, spinal injection, and for siting incisions in patients undergoing spinal surgery (Walsh et al. 2006). A radiographic study in 450 European adult patients showed that the plane crossed the body of L4 or the L4/5 intervertebral disc in 72% of cases (Walsh et al. 2006). These findings support a previous radiographic study of 163 patients in which the figure was 79% (Render 1996) and are similar to subsequent smaller radiographic studies of European (Chakraverty et al. 2007) and American (McGaugh et al. 2007) adults, and a dissection study of African cadavers (Gatonga et al. 2010). The equivalent figure determined by radiography in 72 Korean adults was 64% (Kim et al. 2007), but it is uncertain whether this is a true ethnic difference.

Several studies have shown that the supracristal plane determined by palpation tends to identify a higher vertebral level than the radiographic level in as many as 33–77% of cases (Ievins 1991; Van Gessel et al. 1993; Broadbent et al. 2000; Chakraverty et al. 2007; Kim et al. 2007;). This is more likely in women and patients with a higher body mass index in whom the supracristal plane is most likely to identify the L3/4 intervertebral space (Chakraverty et al. 2007).

Evidence based recommendation: the supracristal plane crosses the body
of L4 or the L4/5 intervertebral disc in most adults. Palpation tends to identify the L3/4 disc space, particularly in women and overweight patients.

2.4.1.2 Renal dimensions

Although each imaging technique has limitations in precisely determining renal length in vivo, there are data for renal dimensions derived from ultrasound scanning, MRI, and computerised tomography studies in relatively large numbers of European and North American adults with healthy kidneys (Emamian et al. 1993; Cheong et al. 2007; Glodny et al. 2009). Each of these studies reported slightly different renal dimensions, but a useful practical guide would be a renal length of approximately 11.5 cm in men and 11 cm in women and a renal width of about 5.5 cm in both sexes. The left kidney is slightly longer than the right by a few millimetres, and there is a weak influence of stature on renal length.

Evidence based recommendation: renal length in white men and women is approximately 11.5 and 11 cm, respectively.

2.4.1.3 Femoral artery in the groin

It is surprising that there should be any controversy about the surface marking of such an important clinical landmark. Once again, the evidence from the literature must be considered in relation to sample size, whether the study was in living subjects or cadavers, the methodology, and the age, gender, and ethnicity of the sample. There are no studies on the effects of obesity on the surface anatomy of the femoral artery although this certainly affects the ease with which the femoral pulse can be detected (Campbell 1988). Cadaver studies have shown that the mid-inguinal point overlies the femoral artery in most cases (Scott and Willan 1991; Koliyadan et al. 2004). There is greater variability in living subjects, but a surface landmark within 1 cm either side of the mid-inguinal point would account for most cases
(Stubbs and Cumberland 1992; Andrews et al. 1996; Hunt and Harris 1996; Sanjay et al. 2006). The midpoint of the inguinal ligament (midway between the anterior superior iliac spine and pubic tubercle) is lateral to this surface landmark and should not be used. It is also worth noting that the inguinal skin crease lies about 6–7 cm inferior to the inguinal ligament (Lechner et al. 1988) and that the femoral artery gives off its profunda femoris branch proximal to this skin crease in most cases (Lechner et al. 1988; Grier and Hartnell 1990).

Evidence based recommendation: the femoral artery in most adults lies immediately below the inguinal ligament (above the inguinal skin crease) within 1 cm either side of the mid-inguinal point (midway between the anterior superior iliac spine and the pubic symphysis).

2.4.1.4 Superior vena cava/right atrial (SVC/RA) junction

Correct placement of central venous catheter tips is important for patient safety. While there is considerable disagreement in the literature regarding optimal positioning, specific guidelines often relate to the SVC/RA junction. Only one study (Hsu et al. 2007) of twenty cancer patients undergoing central venous catheterisation has examined this surface marking, which was located within 1 cm of the lower margin of the third right sternocostal joint in 70% of patients. In 20% (n=4), the junction was found within 1 cm of the superior border of this joint, and in 30% it was within 1 cm of a point located 5 cm below the sternal angle (inferior to the lower border of the right third sternocostal joint). No studies have been conducted examining the effect of a change in posture or the influence of respiration on this surface marking; if movement is significant with either, this may have implications for patient outcomes.

Evidence based recommendation: the SVC/RA junction is within 1 cm of
the superior or inferior border of the right third sternocostal joint, in most adults.

2.5 Conclusions

While there is a consensus on many surface markings, there are also major and minor discrepancies between and even within texts. Also, many texts ignore variation with age, gender, body habitus, ethnicity and phase of respiration; *Gray’s Anatomy* (Standring 2008) was the most comprehensive in this respect. Finally, the three clinical examination texts that were analysed contained comparatively little surface anatomy, frequently omitting clinically important aspects such as the central veins and the bifurcation of the common carotid artery.

In the age of modern medical imaging, surface anatomy remains vital to clinical practice. As such, it must be accurate (evidence based) and relevant (of practical utility). If surface anatomy is not reappraised in the light of new evidence, it will rightly be perceived as being of limited clinical value and belonging to a bygone era.
3 Reappraising central venous surface anatomy with computerised tomography

3.1 Introduction

As discussed in the previous chapter, surface anatomy requires a strong evidence base in order to be considered reliable in the clinic. This is particularly so for the central veins. These are frequently catheterised for resuscitation, cardiac monitoring or delivery of irritant solutions such as parenteral nutrition or chemotherapy (Miller 2010). Their large volume of distribution and close proximity to the heart make them ideal for these purposes. Central venous catheters are generally inserted via the subclavian (see chapter 4) or internal jugular veins (Peris et al. 2010). While there is disagreement regarding the optimal position of the catheter tip (Caruso et al. 2002; Albrecht et al. 2004; Cadman et al. 2004), most guidelines recommend a specific location, often the junction of the superior vena cava with the right atrium (see chapter 5).

In order to position the catheter correctly, the clinician must have an accurate knowledge of the surface anatomy of the brachiocephalic veins, the superior vena cava and its junction with the right atrium. This may help to estimate the length of catheter required more accurately, and aid more accurate placement of the catheter tip relative to the junction of the superior
vena cava and right atrium. Although central venous catheters are often positioned under radiographic guidance, this is not always possible, for example in emergencies or in the anaesthetic room. In such situations, knowledge of the relevant surface anatomy becomes even more important.

Central venous surface anatomy is also relevant to medical and anatomical education. Knowledge of where the azygos vein joins the superior vena cava helps to inform students and clinicians of mediastinal anatomy. Accuracy of surface anatomical knowledge in this context is important lest students and clinicians are misled into using a flawed knowledge of surface anatomy in clinical practice.

Few studies have examined the surface anatomy of the central veins. Indeed, only one study of the junction of the azygos vein with the superior vena cava (Tatar et al. 2008) and one of the junction of the superior vena cava with the right atrium (Hsu et al. 2007) could be identified. Continued building of the evidence base is required to better inform clinicians and students regarding the surface anatomy of the central veins, in order to aid in placement of central venous catheters and improve anatomical knowledge.
3.2 Methods

Sixty chest CT scans (slice thickness 1.2 mm) acquired using a Lightspeed VCT scanner (GE Healthcare, Milwaukee, WI, USA) were obtained from Christchurch Hospital. Sixty-one high definition chest CT scans (slice thickness 0.75 mm) taken using a Sensation 64 scanner (Siemens AG, Erlangen, Germany) were acquired from Dunedin Public Hospital. These were reviewed consensually by two investigators (Samuel Hale and Dr. Ali Mirjalili). Scans were conducted with patients in the supine position with arms abducted and breath-hold at end-tidal inspiration. Data on age and gender were collected for all scans, and self-reported height, weight and ethnicity data were collected where possible (Table 2).

<table>
<thead>
<tr>
<th>Table 2. Details of participants</th>
<th>Mean (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years) (n=103)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>64 (19-89)</td>
</tr>
<tr>
<td>Height (m) (n=41)</td>
<td>1.66 (1.47-1.88)</td>
</tr>
<tr>
<td>Weight (kg) (n=41)</td>
<td>77 (45-155)</td>
</tr>
<tr>
<td>BMI (n=41)</td>
<td>27.7 (15.6-51.8)</td>
</tr>
<tr>
<td>Ethnicity (n=38)</td>
<td>36 (35%) Caucasian</td>
</tr>
<tr>
<td></td>
<td>1 (1%) Asian</td>
</tr>
<tr>
<td></td>
<td>1 (1%) Pacific Peoples</td>
</tr>
<tr>
<td></td>
<td>65 (63%) Unknown</td>
</tr>
</tbody>
</table>

<sup>a</sup> After exclusions (see text for details)

The angle of thoracic kyphosis, taken to be the angle between the superior border of the first thoracic vertebra and the inferior border of the twelfth thoracic vertebra, was measured by a modified Cobb method (Fig. 5) (Fon et al. 1980). Occasionally, the upper or lowermost thoracic vertebrae were not visible. In this case, measurements were taken from the
Figure 5. Modified Cobb method for determining angle of kyphosis ($\alpha$) (Fon et al. 1980).
upper or lower border of the next visible vertebra in order to include as much of the thoracic spine as possible. Subjects with an exaggerated thoracic kyphosis as defined by Fon et al. (1980) (greater than a certain angle, depending on age) were excluded, along with those with a scoliosis greater than 10° as measured by the Cobb method (Cobb 1948). Other exclusions were patients with vertebral compression fractures, space occupying lesions, large pleural effusions or evidence of previous thoracic surgery.

The remaining 103 scans (51 male, 52 female) were analysed to determine surface markings for the following: site of formation of the brachiocephalic veins (BCV) and superior vena cava (SVC), the junction of the azygos vein and SVC, the SVC/right atrial (RA) junction, and the cardiac apex. Scans showing scoliosis less than 10° or cardiomegaly were additionally excluded except for the formation of the BCVs and SVC. One subject had evidence of congenital eventration of the diaphragm and splenomegaly, and another had an aortic stent; these scans were also used only for measurement of the BCVs and SVC. Patients with small pleural effusions were excluded for measurements of the cardiac apex, as was one participant with a hiatal hernia. Finally, the angle between the longitudinal axis of the sternum and the superior border of the medial portion of the clavicle was measured, and subjects with angles greater than 130° (i.e. with hyperabducted arms) were not included in measurements of the distance of the cardiac apex to the midclavicular line.

Axial scans were re-sliced into coronal and sagittal planes using OsiriX 64 bit, version 3.7.1 (© Antoine Rosset, 2003-2010, California, USA). Structures of interest were identified and related to the vertebra, sternum, ribs or clavicles. Vertebrae were identified and their precise level recorded.
in the sagittal view. The first thoracic vertebra (T1), identified by its articulation with the first rib, was used as a reference for more caudal vertebral levels (Fig. 6). Care was taken to consider the possibility of a cervical rib although no instance was found. Structures were referenced to the upper or lower half of the individual vertebral bodies or the intervening intervertebral disc.

For measurements involving the non-vertebral skeleton, slice thickness was increased until the relevant bony structure was visible in the three-dimensional coronal image. Surface projections were described according to the following scheme:

1. The formation of each BCV by the junction of the subclavian and internal jugular veins was identified in the coronal plane and recorded as being either behind, lateral, medial, superior or inferior to the ipsilateral sternoclavicular joint. An imaginary box was visualised around the formation of the BCV, centred on the intersection of the axes of the subclavian and internal jugular veins and reaching the upper angle of their union (Fig. 7A, C). Another was placed around the sternoclavicular joint, to include the medial, lateral, superior and inferior-most points of the clavicular articular surface (Fig. 7B, D). If there was any overlap between these boxes, the formation was recorded as being behind the joint (Fig. 7B). If there was no overlap, its position relative to the joint was recorded as appropriate.

2. The site of formation of the SVC (Fig. 8), defined as the upper junction of the BCVs, was identified in the coronal plane. The SVC/RA junction (Fig. 9), defined as the site where no separation could be seen between the right atrium and right auricle, was identified in the sagittal and transverse planes. Cranio-caudal level
Figure 6. A: Sagittal view showing the first rib (arrow). B: The first thoracic vertebra (T1) was identified by its articulation with the first rib at the costotransverse joint (arrow). (a) shows the neck of the first rib; (b) shows the transverse process of T1.
**Figure 7.** A: Formation of the right brachiocephalic vein, identified in the coronal plane. B: Thick coronal slice showing that the formation lies approximately behind sternoclavicular joint. C: The green box (also shown in A and B) surrounds the formation of the right brachiocephalic vein. It is centred on the intersection of the axes of the right internal jugular and subclavian veins (black lines) and reaches the upper angle of their union. D: The red box (also shown in B) reaches the medial, lateral, superior and inferior limits of the articular surface of the medial end of the clavicle.
Figure 8. A: Formation of the superior vena cava identified in the coronal plane. B: Thick coronal slice showing the superior vena caval formation partially overlapped by the manubrium, at the level of the first intercostal space.
Figure 9. A: The SVC/RA junction identified in the sagittal plane. B: Thick coronal slice. This SVC/RA junction lies posterior to the fourth costal cartilage, just lateral to the sternum.
was referenced to costal cartilages (CC) and intercostal spaces (ICS).

3. The level of the centre of the junction of the azygos vein and SVC was noted in the sagittal plane and its vertebral level recorded. Distance above (+) or below (−) its traditional landmark, the sternal angle, was also measured (along the anterior border of the sternum) (Fig. 10). In one case, where the sternal angle could not be easily identified, this was defined as the midpoint of the junction of the second costal cartilages with the sternum (Standring 2008).

4. The position of the cardiac apex was defined as the most lateral part of the heart, and identified in the sagittal plane. It was recorded both in terms of its cranio-caudal level with reference to ribs, costal cartilages and intercostal spaces and distance from the midline (Fig. 11). Distance medial (−) or lateral (+) to the midclavicular line (MCL) was also recorded; the MCL was defined by identifying the midpoint the clavicle, and projecting this anteriorly (Fig. 12).

3.2.1 Statistical analyses

Data were analysed using PASW Statistics version 18.0.0 (SPSS Inc., Chicago, IL, USA). Means and standard deviations were calculated for continuous data, and medians with interquartile ranges for ordinal data. Associations with age, gender, height, weight, BMI and degree of kyphosis were analysed using full factorial model one-way ANOVA. Each variable was divided into two groups: age was stratified into two groups (< or ≥ 60 years), height into two groups (< or ≥ 1.7 m), weight into two groups (< or ≥ 75 kg), BMI into two groups (< or ≥ 25) and degree of kyphosis into two groups (< or ≥ 40º).
Figure 10. A: Confluence of azygos vein and superior vena cava identified in the sagittal plane. B: A more medial parasagittal plane; the level of the confluence is indicated by the horizontal axis. It is seen to lie 2.5 cm below the sternal angle, at the level of the upper border of T5.
Figure 11. A: The cardiac apex was identified in the sagittal plane, and seen also in (B) the coronal plane. C: Thick coronal view, showing the cardiac apex behind the 5th costal cartilage, 7.8 cm from the midline.
Figure 12. Determining the position of the midclavicular line and the cardiac apex relative to it. A: Acromioclavicular joint identified in thin transverse slice. B: Whole clavicle visible in thick transverse slice. C: Midpoint of the clavicle determined, and midclavicular line (middle vertical line) placed through it, parallel to the vertebral spinous processes.
Figure 12 cont’d. D: Cardiac apex identified 1.5 cm lateral to the MCL.
3.2.2 Reliability

Reliability was determined by repeating measurements in a blinded fashion in one-third of scans, both consensually and individually. Intra-observer repeatability was calculated by comparing initial measurements against the consensual repeat measurements, and inter-observer reproducibility was measured by comparing measurements made by each observer individually. Intraclass correlation coefficients (ICC) and the kappa statistic are equivalent measures of reliability for continuous and discrete data, respectively (Szklo and Nieto 2004). They are graded according to the guidelines set out by Landis and Koch (1977): poor repeatability or reproducibility <0; slight 0.00–0.20; fair 0.21–0.40; moderate 0.41–0.60; substantial 0.61–0.80; and almost perfect 0.81–1.00. ICCs were calculated using PASW Statistics, and kappa and weighted kappa statistics were calculated using an online calculator (http://www.graphpad.com/quickcalcs/kappa1.cfm; GraphPad Software, Inc., San Diego, CA, USA. Last accessed 13 December 2010).

3.2.3 Ethical considerations

Ethical approval was granted by the Lower South Regional Ethics Committee (LRS/09/30/EXP). Māori consultation was also undertaken. Copies of the letter of ethical approval, and the response from the Ngāi Tahu Research Consultation Committee are included in Appendix B.

3.3 Results

The formation of each brachiocephalic vein was consistently located posterior to the ipsilateral sternoclavicular joint. A slightly lateral position was evident in fewer than 10% of cases (Table 3). The formation of the SVC was found most commonly behind the 1st intercostal space (40% of
scans) or 2nd costal cartilage (39%), at a median position of the 2nd costal cartilage; it was partially overlapped by the manubrium. On average, the SVC entered the right atrium at the level of the 4th costal cartilage. The azygos vein joined the SVC at a median level of the lower half of T5 vertebra, which was a mean distance of 2 cm below the sternal angle. The cardiac apex lay on average in the 5th ICS, at a mean of approximately 9 cm from the midline, and about 1 cm lateral to the MCL (Tables 4 and 5).

**Table 3.** Location of the formation of the brachiocephalic vein relative to the ipsilateral sternoclavicular joint

<table>
<thead>
<tr>
<th></th>
<th>Behind (%)</th>
<th>Lateral (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left BCV</strong></td>
<td>100 (97.1%)</td>
<td>3 (2.9%)</td>
</tr>
<tr>
<td><strong>Right BCV</strong></td>
<td>96 (93.2%)</td>
<td>7 (6.8%)</td>
</tr>
</tbody>
</table>

**Table 4.** Measurements to the sternal angle, midline and midclavicular line

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Azygos vein</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to sternal angle</td>
<td>-2.0 ± 1.5</td>
<td>-6.4 – 1.3</td>
</tr>
<tr>
<td><strong>Cardiac apex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to midline</td>
<td>8.7 ± 1.0</td>
<td>6.8 – 11.1</td>
</tr>
<tr>
<td>cm to MCL</td>
<td>0.9 ± 1.0</td>
<td>-1.4 – 3.2</td>
</tr>
</tbody>
</table>
Table 5. Surface markings in relation to costal cartilages and vertebral levels

<table>
<thead>
<tr>
<th></th>
<th>Median (interquartile range)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SVC formation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=103)</td>
<td>2nd CC (1st ICS – 2nd CC)</td>
<td>1st CC – 3rd CC</td>
</tr>
<tr>
<td><strong>SVC/RA junction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=78)</td>
<td>4th CC (4th CC – 5th CC)</td>
<td>3rd CC to 5th ICS</td>
</tr>
<tr>
<td><strong>Azygos/SVC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertebral level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=78)</td>
<td>Lower T5 (Upper T5 – Upper T6)</td>
<td>Upper T4 – T6/7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Cardiac apex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC/ICS (n=73)</td>
<td>5th ICS (5th ICS – 6th CC)</td>
<td>4th ICS – 7th CC</td>
</tr>
</tbody>
</table>

<sup>a</sup> T6/7 represents the intervertebral disc between T6 and T7 vertebrae

Statistically significant associations were seen with age, gender, and BMI (Table 6). The structures examined tended to be lower in the thorax in males and in subjects who were over 60 years of age, compared with females or younger subjects. In scans from individuals with BMI values greater than 25, the SVC tended to form about half a rib space lower than in those with a BMI less than 25, the azygos vein joined the SVC at a higher level, and the cardiac apex was further from the midline (Tables 7 and 8).

Age, gender and BMI were themselves unrelated (p>0.05). As expected, gender and height were significantly associated (p<0.0005) with males being taller on average than females. Therefore, although the right BCV formed laterally to the sternoclavicular joint more commonly in males and participants taller than 1.7 m, this association may be attributed to a gender difference or a difference in height.
Table 6. P values of associations with age, gender and BMI (ANOVA)

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Gender</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left BCV formation</td>
<td>NSD</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td>Right BCV formation</td>
<td>NSD</td>
<td>0.005</td>
<td>NSD</td>
</tr>
<tr>
<td>SVC formation</td>
<td>0.003</td>
<td>0.006</td>
<td>0.017</td>
</tr>
<tr>
<td>SVC/RA junction</td>
<td>&lt;0.0005</td>
<td>0.009</td>
<td>NSD</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm below sternal angle</td>
<td>0.006</td>
<td>0.007</td>
<td>NSD</td>
</tr>
<tr>
<td>vertebral level</td>
<td>&lt;0.0005</td>
<td>NSD</td>
<td>0.01</td>
</tr>
<tr>
<td>Cardiac apex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC/ICS</td>
<td>0.001</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td>cm to midline</td>
<td>NSD</td>
<td>NSD</td>
<td>0.04</td>
</tr>
<tr>
<td>cm from MCL</td>
<td>NSD</td>
<td>NSD</td>
<td>NSD</td>
</tr>
</tbody>
</table>

No significant difference (NSD): p > 0.05
Table 7. Azygos vein and cardiac apex: measurements to sternal angle, midline and midclavicular line related to age, gender and BMI

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azygos vein</td>
<td>-1.4 ± 1.6</td>
<td>-5.7 – 1.3</td>
</tr>
<tr>
<td>cm to sternal angle (n=31)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;60 years</td>
<td>-2.4 ± 1.4</td>
<td>-6.4 – 0</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to sternal angle (n=47)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>-2.4 ± 1.5</td>
<td>-6.4 – 1.2</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to sternal angle (n=40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>-1.5 ± 1.4</td>
<td>-5.1 – 1.3</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to sternal angle (n=38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25</td>
<td>8.3 ± 0.6</td>
<td>6.8 – 9.1</td>
</tr>
<tr>
<td>Cardiac apex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to midline (n=11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;25</td>
<td>8.9 ± 0.8</td>
<td>7.2 – 10.5</td>
</tr>
<tr>
<td>Cardiac apex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm to midline (n=11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8. Surface markings in relation to costal cartilages and vertebral levels, according to age, gender and BMI

<table>
<thead>
<tr>
<th>Age</th>
<th>Median (interquartile range)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>&lt;60 years</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SVC (n=37)</td>
<td>1st ICS (1st ICS – 2nd CC)</td>
<td>1st CC – 2nd ICS</td>
</tr>
<tr>
<td>SVC/RA (n=31)</td>
<td>4th CC (3rd ICS – 4th ICS)</td>
<td>3rd CC – 5th ICS</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vertebral level (n=31)</td>
<td>Upper T5 (Upper T5 – Lower T5)</td>
<td>Upper T4 – Upper T6</td>
</tr>
<tr>
<td>Cardiac apex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC/ICS (n=30)</td>
<td>5th ICS (5th CC – 5th ICS)</td>
<td>4th ICS – 6th CC</td>
</tr>
<tr>
<td><strong>&gt;60 years</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SVC (n=66)</td>
<td>2nd CC (1st ICS – 2nd CC)</td>
<td>1st CC – 3rd CC</td>
</tr>
<tr>
<td>SVC/RA (n=47)</td>
<td>4th CC (4th CC – 5th CC)</td>
<td>3rd CC – 5th ICS</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vertebral level (n=47)</td>
<td>Lower T5 (Lower T5 – Upper T6)</td>
<td>T4/5 – T6/7</td>
</tr>
<tr>
<td>Cardiac apex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC/ICS (n=43)</td>
<td>5th ICS (5th ICS – 6th CC)</td>
<td>4th ICS – 7th CC</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SVC (n=51)</td>
<td>2nd CC (1st ICS – 2nd CC)</td>
<td>1st CC – 3rd CC</td>
</tr>
<tr>
<td>SVC/RA (n=40)</td>
<td>4th CC (4th CC – 5th CC)</td>
<td>3rd CC – 5th ICS</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SVC (n=52)</td>
<td>1st ICS (1st ICS – 2nd CC)</td>
<td>1st CC – 2nd ICS</td>
</tr>
<tr>
<td>SVC/RA (n=38)</td>
<td>4th CC (3rd ICS – 4th ICS)</td>
<td>3rd CC – 5th ICS</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SVC (n=14)</td>
<td>1st ICS (1st CC – 1st ICS)</td>
<td>1st CC – 2nd CC</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vertebral level (n=11)</td>
<td>Lower T5 (Lower T5 – Upper T6)</td>
<td>Upper T5 – T6/7</td>
</tr>
<tr>
<td>&gt;25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SVC (n=27)</td>
<td>2nd CC (1st ICS – 2nd CC)</td>
<td>1st CC – 3rd CC</td>
</tr>
<tr>
<td>Azygos vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vertebral level (n=22)</td>
<td>Upper T5 (T4/5 – Lower T5)</td>
<td>Upper T4 – Lower T6</td>
</tr>
</tbody>
</table>
3.3.1 Reliability

3.3.1.1 Intra-observer repeatability

ICCs showed almost perfect repeatability for all continuous variables (Landis and Koch 1977) (Table 9). Kappa statistics demonstrated substantial repeatability for all ordinal measures except the left BCV, which was almost perfect (Landis and Koch 1977) (Table 10). When kappa statistics were weighted for the degree of discrepancy between initial and repeat measurements, repeatability was improved for all measures, showing that any differences between the measurements were relatively minor. Weighted kappa could not be calculated for the formation of the BCVs as they were described in only two categories: behind or lateral to the sternoclavicular joint. The degree of discrepancy cannot be calculated from dichotomous data.

**Table 9. ICC values for continuous data**

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azygos vein to sternal angle (n=30)</td>
<td>0.98</td>
</tr>
<tr>
<td>Cardiac apex to midline (n=28)</td>
<td>0.91</td>
</tr>
<tr>
<td>Cardiac apex to MCL (n=16)</td>
<td>0.82</td>
</tr>
</tbody>
</table>

**Table 10. Kappa and weighted kappa values for ordinal data**

<table>
<thead>
<tr>
<th></th>
<th>Kappa</th>
<th>Weighted kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCV (n=30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1.00</td>
<td>N/A</td>
</tr>
<tr>
<td>Right</td>
<td>0.63</td>
<td>N/A</td>
</tr>
<tr>
<td>SVC (n=30)</td>
<td>0.68</td>
<td>0.76</td>
</tr>
<tr>
<td>SVC/RA junction (n=30)</td>
<td>0.66</td>
<td>0.83</td>
</tr>
<tr>
<td>Azygos vein vertebral level (n=30)</td>
<td>0.72</td>
<td>0.88</td>
</tr>
<tr>
<td>Cardiac apex (CC/ICS) (n=28)</td>
<td>0.77</td>
<td>0.82</td>
</tr>
</tbody>
</table>
3.3.1.2 Inter-observer reproducibility

ICCs showed almost perfect reproducibility in the distance from the junction of the azygos vein and SVC to the sternal angle and the distance from the cardiac apex to the midline, and substantial reproducibility in the distance from the cardiac apex to the MCL (Table 11). Kappa statistics were similar or poorer compared to intra-observer repeatability (Table 12). Weighted kappa could be calculated for the formation of the right BCV in this instance, as one case was recorded as forming below the sternoclavicular joint. Data were thus classed in three groups rather than two, and degree of discrepancy between initial and repeat measurements could be accounted for in the calculations.

Table 11. ICC values for continuous data

<table>
<thead>
<tr>
<th>Measure</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azygos vein to sternal angle (n=30)</td>
<td>0.98</td>
</tr>
<tr>
<td>Cardiac apex to midline (n=28)</td>
<td>0.94</td>
</tr>
<tr>
<td>Cardiac apex to MCL (n=16)</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Table 12. Kappa and weighted kappa values for ordinal data

<table>
<thead>
<tr>
<th>Measure</th>
<th>Kappa</th>
<th>Weighted kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCV (n=30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0.00</td>
<td>N/A</td>
</tr>
<tr>
<td>Right</td>
<td>0.64</td>
<td>0.70</td>
</tr>
<tr>
<td>SVC (n=30)</td>
<td>0.55</td>
<td>0.64</td>
</tr>
<tr>
<td>SVC/RA junction (n=30)</td>
<td>0.33</td>
<td>0.50</td>
</tr>
<tr>
<td>Azygos vein vertebral level (n=30)</td>
<td>0.84</td>
<td>0.93</td>
</tr>
<tr>
<td>Cardiac apex (CC/ICS) (n=28)</td>
<td>0.75</td>
<td>0.76</td>
</tr>
</tbody>
</table>
3.4 Discussion

Overall, the surface markings for the cardiac apex and the formation of the brachiocephalic veins identified from thoracic CT scans in living subjects are similar to those given in most major anatomy texts. However, while the sternoclavicular joint has been shown to be a reasonably reliable landmark for the formation of the BCVs, it may be more accurate to describe their formation as posterior to the sternal head of the clavicle. Also, given the imprecision with which the MCL is estimated in the clinic (Naylor et al. 1987), it is reasonable to approximate the surface marking of the cardiac apex to a point in the 5th intercostal space in the midclavicular line, i.e. the traditional surface landmark.

In contrast to these findings, the median levels of the formation of the SVC and the SVC/RA junction were one rib lower than generally reported, located posterior to the right second and fourth costal cartilages respectively. The azygos vein was seen to enter the SVC approximately 2 cm below the level of the sternal angle, and about one vertebral body lower than generally stated (see chapter 2).

Few textbooks reviewed in chapter 2 reported variations in these surface markings related to gender differences, age or body habitus. Where this variation was mentioned, it was never quantified; our results present quantitative data on variation with age, gender and BMI previously absent from the surface anatomy literature. Furthermore, a relatively wide range of variation between normal individuals has been demonstrated in all surface markings except the formation of the brachiocephalic veins. This variation is seldom commented on in contemporary anatomical reference texts.
3.4.1 **Repeatability and reproducibility**

The repeatability and reproducibility data demonstrate that these results are indeed reliable. The generally poorer inter-observer reproducibility underlines the strength of consensual reporting in providing accurate and repeatable results. However, inter-observer reproducibility data were often reasonably strong on their own; with the exception of the formation of the left BCV and the SVC/RA junction, ICC and kappa values showed moderate to almost perfect reproducibility (Landis and Koch 1977).

3.4.2 **Previous studies**

To our knowledge, this is the first study to examine the surface markings of the formations of the brachiocephalic veins and SVC *in vivo*, and the first to examine the location of the SVC/RA junction and cardiac apex using CT. There are few previous investigations of the surface anatomy of the central veins (Chukwuemeka *et al.* 1997; Hsu *et al.* 2007; Tatar *et al.* 2008), and very little recent data on the surface anatomy of the cardiac apex.

Chukwuemeka *et al.* (1997) examined 51 chest CT scans to investigate structures commonly stated to lie at the level of the sternal angle. These included the SVC and the arch of the azygos vein. The SVC was almost always found to pass through the plane of the sternal angle during its passage inferiorly to join with the right atrium, but the site of formation of the SVC was not investigated. The level of the arch of the azygos vein was found to vary, with approximately one-third of cases lying above, one-third below and one-third at the level of the sternal angle. *Gray’s Anatomy* (Standring 2008) states that the union of the azygos vein and the SVC lies at the level of the sternal angle, and the arch at the level of T4. However, the level of the sternal angle is given as both T4/5 and T4, so it is unclear whether the arch and the union are positioned in the same transverse plane.
Nevertheless, the surface marking of the union of the azygos vein with the SVC was not analysed.

Tatar et al. (2008) reviewed 103 chest CT scans and found that the arch of the azygos vein and its confluence with the SVC most often lay at the level of the fifth thoracic vertebra. The results of our study support this.

Only one previous study has investigated the surface marking of the SVC/RA junction (Hsu et al. 2007). In 70% of 20 cases, the SVC/RA junction was located within 1 cm of the third right costal cartilage in the supine position, one costal cartilage higher than in our study. This study used a combination of transoesophageal echocardiography (TOE), radiography and palpation. A subclavian venous catheter was inserted using TOE, and the level of the SVC/RA junction was determined indirectly by bending a steel wire to the shape of the catheter as determined by X-ray and placing it over the skin. Many parts of this process may have wide margins of error, which may account for the differences between these results and our results determined with CT.

There is very little recent literature on the surface anatomy of the cardiac apex. However, in a review by O'Rahilly (1952), the apex (defined loosely as the most inferolateral part of the heart on the left side) was stated to lie in the fifth intercostal space about 7 cm from the midline in the supine position. The apex beat, a palpable point superolateral to the anatomical apex (O'Rahilly 1952), was stated to lie in the fourth or fifth intercostal space 8-9 cm from the midline in the supine position, or occasionally above or below this level (O'Rahilly 1952). It was also noted that chest circumference had little or no effect on the distance of the apex from the midline.
Naylor et al. (1987) investigated the accuracy of the midclavicular line as determined by 20 clinicians. Results showed that estimates varied by up to 10 cm from the midline in a given subject. Given this inconsistency between observers, and the minimal influence of chest circumference on the location of the cardiac apex, distance from the midline may be a more useful measure of position of the cardiac apex clinically. However, if care is taken to locate the MCL accurately, this remains a reasonable landmark for the apex. An additional point that should be noted is that the cardiac apex per se is not nearly so important clinically as the palpable apex beat which tends to be in a similar but slightly higher position because of rotation of the heart with systole (Standring 2008).

3.4.3 Merits and limitations of the present study

CT is a versatile imaging modality in common clinical use. It gives clear images in sagittal, coronal and transverse planes, and allows structures to be easily related to the thoracic wall through three-dimensional reconstruction. Importantly, it allows investigation of surface anatomy in living subjects across a range of ages, rather than relying on data from cadavers. Using patient scans from Dunedin and Christchurch Hospitals meant that normal healthy individuals were not needlessly exposed to ionising radiation, and abnormal scans were easily detected and excluded.

However, using patient scans also meant that height, weight and ethnicity data were often unavailable. A greater number of individuals with such data would have increased the power of this study in detecting relevant associations. Also, height and weight were self-reported, allowing potential minor inaccuracies in the calculation of BMI. Individuals with known ethnicity were almost all Caucasian, so this study had almost no power to detect differences related to ethnicity.
Patients were scanned with their arms abducted. Abduction of the arm alters the position of the clavicle, which in turn alters the position of the midclavicular point (and therefore MCL) relative to the rest of the body. MCL was therefore expected to shift slightly medially in these scans. The degree of shift was theoretically calculated using the formula $\cos \theta = \frac{a}{h}$, where $\theta$ is the angle between the superior border of the medial portion of the clavicle and the transverse plane, $a$ is the distance of the MCL from the sternoclavicular joint in the transverse plane, and $h$ is the distance along the clavicle to the midclavicular point (Fig. 13). We found that patients with angles of 30º or less (i.e. 120º or less between the longitudinal axis of the sternum and clavicle [$\leq \theta + 90^\circ$]) had a medial shift of the MCL of no more than 1 cm, compared with individuals in the anatomical position. In only three scans did the angle exceed 120º; one of 121º, and two greater than 130º. Those greater than 130º were excluded from further analysis. As previously discussed, the MCL is approximate in clinical practice, so this small medial shift was deemed acceptable. However, it may mean that the true average distance from the cardiac apex to the MCL is slightly less than that presented here, i.e. the cardiac apex is on average at most 1 cm lateral to the MCL.

A final limitation worth considering is the effect of respiration. The CT scans used in this study were obtained from individuals who were asked to hold their breath at the end of normal inspiration. Thus, the effects of respiratory excursion on our surface anatomy landmarks could not be evaluated and might account for minor differences with previous CT studies.
Figure 13. Calculation of the theoretical shift of the midclavicular line with changing position of the clavicle. $h$ is the distance from the midpoint of the clavicle to the sternoclavicular joint; $a$ is the distance from the sternoclavicular joint to the midclavicular line in the transverse plane; and $\theta$ is the angle between the clavicle and transverse plane.
3.4.4 Future directions

Further work is already in progress using this data set to establish accurate surface markings for other thoracic structures, such as the lower border of the lungs, the sternal angle and diaphragmatic apertures.

3.5 Conclusion

Some surface markings, such as that for the formation of the brachiocephalic veins and the position of the cardiac apex, are generally reported accurately in contemporary anatomical reference texts. Others, such as the formation of the superior vena cava, the site where it is joined by the azygos vein, and its subsequent junction with the right atrium were found to differ markedly from those surface markings reported in textbooks, often by a whole rib or vertebral level. The vascular structures investigated tended to be lower in the thorax in males and in subjects over 60 years of age, and BMI also influenced the position of central venous surface markings. There is also a relatively wide range of variation between normal individuals that is often ignored in reporting surface anatomy.

This study has provided evidence based surface markings for the central veins and the cardiac apex. These may be used to better inform both students and clinicians of clinically relevant surface anatomy.
Defining the surface anatomy of the subclavian vein by ultrasound

4.1 Introduction

Central venous catheters are in widespread hospital use for central venous pressure monitoring, the administration of irritant solutions into the blood, and for repeated venous access. They are also utilised in emergency situations for the rapid transfusion of fluids (Miller 2010). Large central veins have relatively high flow rates and large volumes of distribution, making them ideal for these purposes. Often, central veins such as the subclavian (SCV) are the only readily available points of access to the venous system (Miller 2010).

Although catheterised less frequently than the internal jugular vein (Peris et al. 2010), the SCV is an important point of access to central veins (Miller 2010). Continuing from the axillary vein at the outer border of the first rib, the SCV travels 3 to 4 cm (Moosman 1973) to join the internal jugular vein just posterior to the medial end of the clavicle (Standring 2008). It is held open by a prominent tunica adventitia (Grant 2006) and by attachments to adjacent structures, such as the pretracheal fascia and subclavius muscle (Fortune and Feustel 2003). This connective tissue support makes the SCV particularly valuable in hypovolaemia, when other veins may be collapsed.
(Miller 2010). Its location also allows for less patient discomfort compared to the internal jugular or femoral veins, if a venous catheter is required in the longer term (Miller 2010).

However, subclavian venous catheterisation is not without risk. Relations with the nearby pleura and subclavian artery mean that complications due to a misplaced needle may be life threatening. These include pneumothorax (incidence 1.5-3.1%) and arterial puncture (3.1-4.9%), leading to haemorrhage or haemothorax (0.4-0.6%) (McGee and Gould 2003). Risk increases with the number of attempts at catheterisation (Mansfield et al. 1994), so it is important to optimise the likelihood of successful catheterisation on the first pass of the needle. Ultrasound guidance has been trialled with this aim, but it is unhelpful at this location due to the acoustic shadow cast by the clavicle; indeed, it was found less reliable than catheterisation using surface anatomy alone (McGee and Gould 2003).

Several small studies have shown that placing the patient in different positions alters the diameter of the subclavian vein and its relationship with the clavicle, potentially facilitating or impeding catheterisation. There is uncertainty in the literature as to the optimal position and only a few studies have been undertaken addressing this issue ( Fortune and Feustel 2003). In an ideal position, the SCV would be maximally distended; increasing the size of the target improves the chance of penetration (Kawano and Yoshimine 2007). The distance between the subclavian vein and the clavicle should also be minimised, so the latter may be used more reliably as a guide (Tan et al. 2000). For this reason, the clinician should aim to puncture the SCV at the point where it lies closest to the clavicle. In order to minimise the number of needle passes, and consequently risk, the surface anatomy and the effect of body position on the subclavian vein need to be
better characterised. The clinician may therefore be better informed and, hopefully, patient outcomes improved.

4.2 Methods

4.2.1 Participants

Fifty healthy volunteers (25 female, 25 male; mean age 35 years [range 19–68 years]; and mean BMI 24.0 [range 16.5–37.0]) were recruited by word of mouth advertising (Table 13). Participants confirmed that they had no history of central venous catheterisation or chest surgery, and no known malformation of the neck or upper chest. Height was measured with a stadiometer (Seca stadiometer #214, seca gmbh & co. kg., Hamburg, Germany) and weight using clinical grade digital scales (Seca scales #813, seca gmbh & co. kg., Hamburg, Germany) prior to each scan.

Table 13. Details of participants (n=50)

<table>
<thead>
<tr>
<th></th>
<th>Mean (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>34.8 (19.3-68.7)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.6 (46-123.1)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.73 (1.57-1.96)</td>
</tr>
<tr>
<td>BMI</td>
<td>24.0 (16.5-37.0)</td>
</tr>
</tbody>
</table>

4.2.2 Scanning protocol

Participants were examined in the supine position with 10° of head-down tilt, and the head turned approximately 45° away from the side being scanned.
The SCV was scanned bilaterally by an experienced clinical sonographer (Gerry Hill) using a Sonoline Antares ultrasound system coupled to a VF13-5 transducer (13–5 MHz, linear array) (Siemens AG, Erlangen, Germany) (Fig. 14). The transducer was positioned above the clavicle, and the beam directed posteroinferiorly. Valves in the subclavian vein were identified as a point of anatomical interest, and their distance from the confluence of the internal jugular vein (IJV) and the SCV were recorded. Venous diameter and distance of the vein from the superior border of the clavicle (Fig. 15) were measured three times at the point where the vein lay closest to the superior border of the clavicle. This point was then marked on the skin with a felt-tip marker, along with the midpoint of the upper border of the jugular notch and the sternoclavicular and acromioclavicular joints as determined by ultrasound (Fig. 16). The distance of this point to the jugular notch and the clavicular length were measured with a fabric measuring tape. Finally, the angle between the vein and the clavicle in the transverse plane was calculated from a triangle formed by three points marked on the skin (Fig. 16): the point where the vein was closest to the clavicle (B); an arbitrary point on the clavicle approximately 1–2 cm medial to B along the axis of the clavicle (D); and the point at the latter site where the superior border of the vein was furthest from the clavicle (C). A standard 1L bag of 0.9% saline wrapped in a small towel was then placed longitudinally in the midline between the medial borders of the scapulae causing passive shoulder retraction, and all measurements except for clavicular length and observation of venous valves repeated.

4.2.3 Analysis

Data were analysed using Microsoft ® Excel ® 2008 for Mac version 12.2.4 (Microsoft Corporation, Redmond, WA, USA) and PASW Statistics version 18.0.0 (SPSS Inc., Chicago, IL, USA). Two-tailed paired t-tests
Figure 14. A participant undergoing an ultrasound scan of the right SCV.
Figure 15. Typical B-mode ultrasound image of the left SCV. A–B (Dist A) = distance of the SVC from the superior border of the clavicle (CLAV). B–C (Dist B) = venous diameter. The external jugular vein (EJV) is seen between the clavicle and SCV. The acoustic shadow cast by the clavicle obscures its own posterior and inferior borders and part of the SCV.
Figure 16. Marks on the skin used to take measurements (above) and their corresponding structures (below). A: Acromioclavicular joint. B: Point where the SCV and clavicle were closest together. C: The point where the SCV and clavicle were furthest apart at D: an arbitrary point on the clavicle approximately 1–2 cm medial to B along the axis of the clavicle. E: Sternoclavicular joint. F: Upper border of the midpoint of the jugular notch. Adapted from McGee and Gould (2003).
were used to examine changes within individuals with shoulder retraction. Age was stratified into two groups (≤ 30 and ≥ 30 years of age), as was BMI (≤ 25 and ≥ 25). Relationship to age, gender and BMI was analysed using full factorial model one-way ANOVA. Fisher's Exact test was used to examine the presence or absence of valves. Repeatability was determined by repeating measurements on 10 participants, with at least one week between scans and the investigators blinded to previous results. Technical Error of Measurement (TEM), relative TEM (rTEM) and two-way random single measure Intraclass Correlation Coefficients (ICC) were calculated (Weinberg et al. 2005). ICCs were graded according to the guidelines set out by Landis and Koch (1977) (see methods, chapter 3). Repeatability of angle measurements was not tested due to insufficient numbers.

4.2.4 Ethical considerations

Ethical approval was granted by the University of Otago Human Ethics Committee (reference code 10/126). A copy of the letter of approval, the participant information sheet, consent form and proforma are available in Appendix D. Māori consultation was also undertaken, and the letter of response from the Ngāi Tahu Research Consultation Committee is also available in Appendix D.

4.3 Results

One volunteer was excluded due to a history of repeated fractures of the clavicles. This participant was replaced. In another volunteer with a BMI of 30.9, measurements taken of the left SCV after shoulder retraction were not reliable because excess adipose tissue created difficulties in acquiring the relevant images. In almost all cases, the SCV was situated posterior and slightly inferior to the clavicle at the point where its upper border was
closest to the clavicle on ultrasound. In one subject, the right SCV ran medially in a more inferior position making it difficult to image after shoulder retraction, such that the data could not be obtained in repeat scans. The external jugular vein (typically a tributary of the SCV) often entered the SCV at the point where sonographic measurements were taken.

Venous valves were identified in 91% of participants in the right SCV, and 85% on the left (n=49). There was no significant difference in this frequency between sides (p=0.189, n=48). Only one participant had no identifiable valves on either side, and three participants had two valves in the right SCV. Where only one valve was identified, it was sited on average approximately 2 cm from the confluence of the IJV and SCV (n=40) on both sides.

Clavicular length, measured by ultrasound and fabric measuring tape, was on average 15.8 cm in males (SD = 1.6, range 12.0–19.6) and 14.4 cm in females (SD = 0.9, range 12.3–16.0). At the point where the SCV and clavicle were closest (point B), the superior border of the SCV lay approximately 9 mm from the superior border of the clavicle bilaterally. This point was on average 7.4 cm (SD = 1.0, range 5.4–9.0) from the midpoint of the jugular notch on the left, and 7.1 cm (SD = 1.1, range 4.5–9.8) on the right, and lay approximately at the junction of the medial and middle thirds of the clavicle. The left SCV measured 10.2 mm in diameter (SD = 2.4, range 6.6–15.8), and the right 10.7 mm (SD = 2.2, range 6.0–16.0). The angle between the SCV and clavicle was approximately 45–50º bilaterally (range 11–92º). These results are shown in Table 14.

Venous diameter decreased by approximately 10% after passive shoulder retraction (p<0.0005). The vein also moved slightly closer to the clavicle
(p<0.05), and slightly nearer to the jugular notch (on average 3 mm medially) (p<0.05) (Table 14). There was no significant change in angle.

**Table 14.** Measurements characterising the relationship of the SCV to the clavicle, and changes after passive shoulder retraction (n=50)

<table>
<thead>
<tr>
<th></th>
<th>Mean without bag ± SD (range)</th>
<th>Mean with bag ± SD (range)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCV to clavicle (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>9.0 ± 2.8 (5.0 – 16.6)</td>
<td>8.1 ± 2.3 (4.6 – 15.0)a</td>
<td>0.001</td>
</tr>
<tr>
<td>Right</td>
<td>8.7 ± 2.9 (3.3 – 16.3)</td>
<td>8.2 ± 2.4 (4.2 – 13.6)</td>
<td>0.032</td>
</tr>
<tr>
<td><strong>Venous diameter (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>10.2 ± 2.4 (6.6 – 15.8)</td>
<td>9.0 ± 2.4 (2.7 – 14.0)a</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Right</td>
<td>10.7 ± 2.2 (6.0 – 16.0)</td>
<td>9.7 ± 2.6 (4.3 – 16.9)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td><strong>Distance from mid-jugular notch (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>7.4 ± 1.0 (5.4 – 9.0)</td>
<td>7.1 ± 1.1 (4.9 – 9.8)</td>
<td>0.019</td>
</tr>
<tr>
<td>Right</td>
<td>7.1 ± 1.1 (4.5 – 9.8)</td>
<td>6.8 ± 1.0 (4.7 – 9.3)</td>
<td>0.036</td>
</tr>
<tr>
<td><strong>Angle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>47° ± 13 (19 – 84)</td>
<td>46° ± 12 (24 – 71)</td>
<td>0.808</td>
</tr>
<tr>
<td>Right</td>
<td>44° ± 13 (18 – 70)</td>
<td>50° ± 20 (11 – 92)</td>
<td>0.120</td>
</tr>
</tbody>
</table>

\(a n=49, b n=36\)

There was no significant difference in measurements between left and right sides, except in venous diameter after shoulder retraction (p=0.015).

Several associations were apparent with age, gender and BMI (Table 15). Participants over 30 years of age tended to have a greater distance between the vein and clavicle at the point where they were closest (p<0.05). Males tended to have greater venous diameter and distance from the jugular notch (p<0.05) (Table 16, Fig. 17). Greater BMI was associated with greater diameter on both sides (p<0.05) (Tables 15 and 16). Gender was not associated with BMI (p=0.495).
Table 15. Significance of associations with age, gender and BMI (ANOVA) without passive shoulder retraction

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Gender</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCV to clavicle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0.045</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td>Right</td>
<td>0.006</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td><strong>Diameter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>NSD</td>
<td>0.02</td>
<td>0.002</td>
</tr>
<tr>
<td>Right</td>
<td>NSD</td>
<td>&lt;0.0005</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>Distance to notch</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>NSD</td>
<td>0.012</td>
<td>NSD</td>
</tr>
<tr>
<td>Right</td>
<td>NSD</td>
<td>0.002</td>
<td>NSD</td>
</tr>
</tbody>
</table>

No significant difference (NSD): p > 0.05
Table 16. Measurements stratified by age, gender and BMI without passive shoulder retraction

<table>
<thead>
<tr>
<th>Age Group</th>
<th>SCV to clavicle (mm)</th>
<th>Mean ± SD (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18-29.9 years (n=21)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>7.9 ± 2.5 (5.1 – 14.2)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>7.3 ± 2.4 (3.3 – 12.9)</td>
</tr>
<tr>
<td></td>
<td>30-49.9 years (n=19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>10.1 ± 2.9 (6.2 – 16.6)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>10.0 ± 2.7 (6.6 – 16.3)</td>
</tr>
<tr>
<td></td>
<td>50+ years (n=10)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Left</td>
<td>9.2 ± 2.7 (5.0 – 13.6)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>9.3 ± 2.8 (5.2 – 13.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Venous diameter (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (n=25)</td>
<td>Left</td>
<td>11.0 ± 2.5 (7 – 15.8)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>11.8 ± 2.4 (6.0 – 16.0)</td>
</tr>
<tr>
<td>Female (n=25)</td>
<td>Left</td>
<td>9.5 ± 2.0 (6.6 – 13.9)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>9.6 ± 1.4 (7.7 – 11.8)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>To jugular notch (cm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (n=25)</td>
<td>Left</td>
<td>7.7 ± 1.0 (5.5 – 9.0)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>7.5 ± 1.0 (5.8 – 9.0)</td>
</tr>
<tr>
<td>Female (n=25)</td>
<td>Left</td>
<td>7.0 ± 0.9 (5.4 – 8.6)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>6.6 ± 0.9 (4.5 – 8.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BMI</th>
<th>Venous diameter (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI &lt; 25 (n=30)</td>
<td>Left</td>
<td>9.3 ± 2.2 (6.6 – 15.8)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>9.9 ± 2.1 (6.0 – 14.5)</td>
</tr>
<tr>
<td>BMI &gt; 25 (n=20)</td>
<td>Left</td>
<td>11.6 ± 2.0 (8.1 – 15.5)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>11.9 ± 1.8 (9.9 – 16)</td>
</tr>
</tbody>
</table>
Figure 17. Distribution of distances to the mid-jugular notch (cm) with and without passive shoulder retraction.
4.3.1 Repeatability

The TEM, rTEM and ICC values are shown in Table 17. All rTEM values showed greater than 5% variation between measurements, the threshold for precision (Weinberg et al. 2005). ICC values showed generally slight to fair agreement between initial and repeat measurements, with the exceptions of venous diameter in the left SCV which showed moderate to substantial repeatability irrespective of shoulder position, and the distance of the left SCV to the jugular notch with shoulder retraction, which was poor (Landis and Koch 1977).
Table 17. Repeatability statistics (n=10)

<table>
<thead>
<tr>
<th></th>
<th>TEM</th>
<th>rTEM</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCV to clavicle</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall mean (n=50) = 8.5 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Without retraction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>2.6 mm</td>
<td>28%</td>
<td>0.39</td>
</tr>
<tr>
<td>Right</td>
<td>2.6 mm</td>
<td>30%</td>
<td>0.09</td>
</tr>
<tr>
<td><em>With retraction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1.6 mm</td>
<td>19%</td>
<td>0.45</td>
</tr>
<tr>
<td>Right</td>
<td>1.6 mm</td>
<td>19%</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>Venous diameter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall mean (n=50) = 9.9 mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Without retraction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1.0 mm</td>
<td>10%</td>
<td>0.77</td>
</tr>
<tr>
<td>Right</td>
<td>1.5 mm</td>
<td>13%</td>
<td>0.36</td>
</tr>
<tr>
<td><em>With retraction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1.4 mm</td>
<td>15%</td>
<td>0.59</td>
</tr>
<tr>
<td>Right</td>
<td>2.0 mm</td>
<td>20%</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Distance to jugular notch</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall mean (n=50) = 7.1 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Without retraction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0.7 cm</td>
<td>10%</td>
<td>0.37</td>
</tr>
<tr>
<td>Right</td>
<td>1.0 cm</td>
<td>14%</td>
<td>0.03</td>
</tr>
<tr>
<td><em>With retraction</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>0.8 cm</td>
<td>11%</td>
<td>-0.34</td>
</tr>
<tr>
<td>Right</td>
<td>0.6 cm</td>
<td>9%</td>
<td>0.47</td>
</tr>
</tbody>
</table>

\(^a\) n=9
4.4 Discussion

The SCV was clearly visible bilaterally in all but one participant, approximately 9 mm posteroinferior to the superior border of the clavicle. Its overall mean diameter was 9.9 mm, and it passed closest to the clavicle at a point just over 7 cm from the midpoint of the jugular notch on both sides. The point where they were closest moved slightly but significantly medially after passive shoulder retraction. Males tended to have greater venous diameter and distance from the jugular notch. Participants with BMI greater than 25 also tended to have greater venous diameter, and those over the age of 30 years tended to have greater distance between the superior border of the clavicle and the superior border of the SCV.

Passive shoulder retraction brings the upper border of the SCV slightly but significantly closer to the clavicle. This may improve the likelihood of successful catheterisation in theory, although this decrease is probably of negligible clinical relevance (~1 mm). However, passive shoulder retraction also causes a decrease in venous diameter. While this change is again relatively small (~1 mm), it may reduce the chance of successful venous puncture on the first pass of the needle. As such, the incidence of serious complications such as pneumothorax or arterial puncture may increase in this position. Also, participants often found the presence of the saline bag mildly uncomfortable. Subclavian venous catheterisation is therefore probably best performed without passive shoulder retraction. The slight medial shift of the point where the SCV and clavicle are closest is of dubious clinical consequence. The findings regarding angle may be used as a rough guide for clinicians when accessing the SCV percutaneously via an infraclavicular approach, but the mean angle of around 45º should not be
accepted uncritically because of the wide variation seen between individuals.

It is unclear why there was a significant difference in venous diameter between left and right sides with shoulder retraction and not without, but this should be interpreted cautiously since the difference between left and right was only 0.2 mm greater than without shoulder retraction. It is possible that the greater diameter in the right SCV in general is related to handedness, but this was not recorded in our proforma.

The present study is the largest to have examined SCV diameter and the distance between the SCV and the clavicle with ultrasound. Is the first study to establish the point along the clavicle where the SCV passes closest to it. Other relevant studies have examined the vein at the junction of the medial and middle thirds of the clavicle, approximately where the needle is intended to enter the vein if it penetrates the skin inferior to the mid-clavicle (McGee and Gould 2003). This is the first study to use ultrasound to investigate changes in the angle between the SCV and clavicle in the transverse plane, with and without shoulder retraction. It is also the first study to examine the association between SCV parameters and age and BMI, and the largest to investigate any association with gender.

Associations of venous diameter and distance from the upper border of the SCV to the clavicle with age, gender and BMI are interesting, though they are of limited value in influencing the procedure of subclavian venous catheterisation. The gender difference in the distance from the jugular notch to the point where the SCV and clavicle were closest is, however, of potential clinical significance. These results showed that in approximately two thirds of males, the SCV and clavicle were closest within 1 cm of a
point 7.5 cm from the midline; this is approximately 1 cm lateral to the
equivalent point in females (Table 16; Fig. 17). In both genders, this equates
to the junction of the medial and middle thirds of the clavicle. However, it
must be noted that there is considerable variation in this measurement
between individuals (Table 16; Fig. 17), so aiming the needle towards this
precise point will not yield a 100% success rate on the first pass of the
needle. Nevertheless, inserting the needle with these landmarks in mind
may at least facilitate catheterisation, thereby minimising complications and
improving patient outcomes.

4.4.1 Repeatability

The results of the tests of repeatability may be affected by a learning
curve; the subjects who were repeatedly scanned usually had their initial
scans early in the study period. Repeat scans were performed closer to the
end of the study. With increasing experience of scanning this region, the
accuracy of measurements may have improved. This may account for some
of the differences between initial and repeat measurements. 20% of the total
study sample underwent repeat scans but this equates to only 10
participants. It is possible that a larger group of repeat subjects or repeated
measures would yield improved repeatability data.

4.4.2 Previous studies

It has been previously shown that body posture affects the size and
position of the SCV, facilitating or impeding catheterisation (Land 1971;
Land 1972; Jesseph et al. 1987; Tan et al. 2000; Fortune and Feustel 2003;
Rodriguez et al. 2006; Kawano and Yoshimine 2007; Kim et al. 2008).
While various postures have been advocated, there is no clear consensus in
the literature regarding optimal body position (Fortune and Feustel 2003).
However, most authors have recommended combinations of head-down tilt,
passive shoulder retraction and turning of the head to the contralateral side (McGee and Gould 2003; Boon et al. 2007; Braner et al. 2007; Taylor and Palagiri 2007; Hamilton 2008; Miller 2010). A 10-15° head-down tilt is frequently used to increase central venous pressure, distending the vein (Boon et al. 2007). Passive shoulder retraction is partly intended to aid correct orientation of the needle in the coronal plane (Thompson and Calver 2005). The head may be turned to the contralateral side with the aim of placing tension on the vein (Land 1972), or simply for patient comfort (Grant 2006). Turning the head is not believed to change the relationship of the SCV and clavicle (Land 1971, 1972). However, very little research has been conducted in this area.

Previous studies investigating the effects of posture on the subclavian vein have been small, each with no more than twenty participants (Jesseph et al. 1987; Tan et al. 2000; Fortune and Feustel 2003; Rodriguez et al. 2006; Kawano and Yoshimine 2007; Kim et al. 2008). Differences with age, body habitus and gender have been almost completely ignored.

Fortune and Feustel (2003) were the only authors to use ultrasound to examine the distance between the SCV and clavicle, which they analysed at the junction of the medial and middle thirds of the clavicle. They deemed these structures to be closest with 15° head-down tilt and shoulder retraction. However, in their study, venous diameter was slightly but significantly decreased compared to head-down tilt alone. Rodriguez et al. (2006) recommended using head-down tilt with the head turned away; in 18 adults (6 female), shoulder retraction was seen to decrease the cross-sectional area of the vein on ultrasound by 15% in both genders. Proximity to the clavicle was not measured.
Kim et al. (2008) examined the SCV in 20 adult males with ultrasound, and found no significant change in diameter with head-down tilt. In contrast, Kawano and Yoshimine (2007) demonstrated a statistically significant increase in the diameter of the SCV with increasing head-down tilt.

Jesseph et al. (1987) used magnetic resonance imaging in five adult subjects to show that the vein is compressed by the clavicle with shoulder retraction, which may actually impede catheterisation. Tan et al. (2000) noted that shoulder retraction increased contact between the SCV and clavicle in cadavers, and, in contrast, suggested that this would facilitate venous access.

Only one study investigated the angle between the clavicle and SCV (Land 1971) in the coronal plane. Using contrast venography, it showed that the right SCV passed superomedially at an average angle of 42º to the clavicle (range 13º-77º). Changes with body position were not examined.

The optimal site of percutaneous puncture via the infraclavicular approach is also disputed (Table 18). Many authors recommend piercing the skin inferior to the midpoint of the clavicle, to enter the SCV at approximately the junction of the medial and middle thirds of the clavicle (Tan et al. 2000). Some suggest a point below the junction of medial and middle thirds of the clavicle, penetrating the SCV nearer its junction with the internal jugular vein. Others advocate inserting the needle lateral to the midpoint of the clavicle (Tan et al. 2000). The results of our study support inserting the needle at a point below the mid-clavicle, angling 45º posteriorly to the longitudinal axis of the clavicle and aiming to puncture the SCV at the junction of the middle and medial thirds of the clavicle. This
should facilitate puncture of the SCV where it passes closest to the clavicle, making the clavicle a more reliable guide to SCV access.

Table 18. Published recommended points of needle entry for infraclavicular SCV access

<table>
<thead>
<tr>
<th>CLAVICLE</th>
<th>Junction of medial/middle thirds</th>
<th>Midclavicular region</th>
<th>Lateral to mid-clavicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braner et al. (2007)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Boon et al. (2007)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Hamilton (2008)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Kilbourne (2009)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>McGee and Gould (2003)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Miller (2010)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Taylor and Palagiri (2007)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Thompson and Calver (2005)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

4.4.3 Limitations of the present study

Ultrasound was chosen because it is a safe, non-invasive technique used frequently in the clinic. Measurements were completed within 30 minutes, meaning that changes seen are more likely to be due to effects of position rather than minor physiologic changes, such as possible variation in venous distension with level of hydration (Fortune and Feustel 2003). However, scanning the SCV in obese participants was difficult due to excess adipose tissue. Furthermore, the clavicle casts an acoustic shadow that obscures its own inferior border and the anterior portion of the SCV (Fig. 15). The distance between the SCV and the clavicle was therefore determined from the visible superior border of both structures. These measurements are hence an indication of the maximum distance of the SCV from the clavicle at the point where they are closest. The SCV undoubtedly lies closer to the
clavicle at this point than has been measured, possibly even adjacent to the bone, but this cannot be determined with ultrasound.

The angle between the upper border of the SCV and the upper border of the clavicle in the transverse plane was measured over the skin contours of the supraclavicular fossa. It is therefore likely that the actual angle is less than that measured; this would be better determined using CT or MRI.

As with most studies, the power would have been greater if more participants had been included which would have allowed other variables such as ethnicity to be examined. However, a sample size of 50 is certainly a reasonable size and, as stated earlier, the largest ultrasound study to date.

4.4.4 Future directions

Changes in subclavian venous anatomy on turning the head require further investigation. Two previous studies using contrast venography showed no changes in this respect (Land 1971, 1972), however this technique provides little information on the three-dimensional relations of the vein. Ultrasound or CT may be better ways to investigate this.

Further examination of the angle between the SCV and clavicle in the transverse plane using techniques such as CT or MRI may also improve rates of successful catheterisation.

A large clinical study examining the effect of patient position on success and complication rates of subclavian venous catheterisation may help to resolve disputes regarding which position is optimal. This would have to be prospective, randomised and controlled in design, and should take the
performing clinician's level of experience and patient age, gender and BMI into account.

4.5 Conclusions

Infraclavicular subclavian venous catheterisation is probably best performed without shoulder retraction. This is not only more comfortable for the patient but maximises venous diameter. The SCV is closest to the clavicle at about 7.5 ± 1 cm from the jugular notch in males, and 6.5 ± 1 cm in females, which equates approximately to the junction of the medial and middle thirds of the clavicle. Here, the upper border of the vein lies approximately 1 cm posteroinferior to the superior border of the clavicle, and just below this point the vein lies even closer to the clavicle. This knowledge may facilitate successful percutaneous puncture of the SCV with the first pass of the needle, minimising the risk of serious complications.

The findings of this study were presented at the annual meeting of the Australian and New Zealand Association of Clinical Anatomists in Hobart, Australia, 2-3 December 2010. The presentation abstract is available in Appendix F. *Clinical Anatomy* 2011 (in press).
5 The surface anatomy of the SVC/RA junction: an unsuccessful sonographic investigation

5.1 Introduction

As discussed in the previous chapter, central venous catheters are frequently used in modern hospitals, particularly for administration of irritant solutions or rapid intravenous fluid delivery (Miller 2010). Correct placement of the catheter tip is important in minimising the incidence of serious complications, such as thromboembolism (occurring in up to 30% of cases) (Cadman et al. 2004), vascular perforation and/or cardiac tamponade (in around 0.2% of cases) (Caruso et al. 2002; Hsu et al. 2007). While there is considerable disagreement in the literature regarding the optimal position of the catheter tip (Caruso et al. 2002; Albrecht et al. 2004; Cadman et al. 2004), most guidelines recommend specific positions within the central veins, often in relation to the junction of the superior vena cava and right atrium (SVC/RA junction). Unless the catheter is inserted under radiographic control, the clinician must estimate the catheter tip position from surface anatomy. It is generally stated that the SVC/RA junction lies behind or close to the third right costal cartilage (Hsu et al. 2007; Standring 2008) although there has been only one report of the validity of this surface
marking in living subjects (Hsu et al. 2007).

There are no studies examining variation in the position of the SVC/RA junction with posture. If the location of the junction changes significantly with posture, optimal placement of the catheter tip in the supine position may be suboptimal when the patient sits up in bed. This may lead to an increased risk of complications.

5.2 Methods

5.2.1 Overview

This study of healthy volunteers aimed to investigate the accuracy of the right third costal cartilage as a surface marking for the SVC/RA junction, and how this might vary with posture.

5.2.2 Participants

Up to 50 healthy volunteers over the age of 18 years were planned to be recruited by word of mouth advertising and posters in the Dunedin Public Hospital and University of Otago. They were required to have no history of cardiac or major respiratory problems, or abnormalities of spinal curvature. Gender, age (in years and months), body weight (kg) and height (m) were to be recorded, and BMI calculated.

5.2.3 Scanning protocol

Subjects would be asked to expose the upper chest. The SVC/RA junction was to be located by an experienced sonographer with a P10-4 transducer (10–4MHz, phased array) coupled to a Sonoline Antares ultrasound machine (Siemens AG, Erlangen, Germany), in both the supine
and upright seated positions. The intercostal spaces along the right sternal border were to be used as sonographic windows into the thoracic cavity. The position of the SVC/RA junction was to be recorded in terms of intercostal spaces and costal cartilages, and measurements repeated twice to ensure accuracy.

5.2.4 Ethical considerations

Ethical approval was granted by the University of Otago Human Ethics Committee (reference code 10/126), and Māori consultation was also undertaken. A copy of the letter of approval, participant information sheet, consent form and advertisement, and the response from the Ngāi Tahu Research Consultation Committee can be found in Appendix G.

5.3 Results

This study proved unsuccessful due to difficulties in imaging the SVC/RA junction using ultrasound, attempted with one volunteer. The greatest challenge was the presence of lung tissue between the transducer and the vascular junction itself (Fig. 18). Air acts as a barrier past which no meaningful ultrasound signals can be acquired (Hoskins et al. 2010). When alternate sonographic windows were trialled (the liver [Fig. 19], root of the neck and spleen), the SVC/RA junction could not be imaged due to poor transducer manoeuvrability and penetration of the sound waves.

5.4 Discussion

Despite careful planning and the consideration of technical aspects such as acoustic windows, this study proved to be unsuccessful. In order to better understand these difficulties, a discussion of basic ultrasound physics is required.
Figure 18. Typical ultrasound image through an intercostal space, just lateral to the sternum. Acoustic shadows are seen beneath each rib. No discernable structures are visible beyond the thoracic wall.

Figure 19. Duplex image of cardiac chambers visible through the liver.
5.4.1 Physics of ultrasound

5.4.1.1 Acoustic impedance and specular reflectors

Acoustic impedance \( (z) \) is a property of every material, related to its density and compressibility. It is an expression of the resistance a material poses to a sound wave passing through it (Hennerici et al. 2006). Different tissues have different acoustic impedances. The area where tissues meet is called a specular reflector (colloquially known as an interface). When a sound wave passes across a specular reflector, part of the wave is reflected, and its detection by the transducer is used to construct an ultrasound image (Fig. 20A) (Hennerici et al. 2006).

The difference in acoustic impedances at a specular reflector can be used to predict the size of the reflected wave through calculation of the amplitude \( (R) \) reflection coefficient (Fig. 20B) (Hoskins et al. 2010). A greater change in impedance will give a greater \( R \), and will result in a reflected wave of greater amplitude and intensity (Hennerici et al. 2006).

5.4.1.2 Air and ultrasound

Using the intercostal spaces as windows to visualise the SVC/RA junction was not possible due to the presence of lung tissue in the costomediastinal recess (Fig. 18). The \( R \), at the interface between air and soft tissue such as liver is 0.9995, showing that almost all of the sound waves are reflected without passing through. The massive change in impedance (air: \( 430 \text{ kg m}^{-2}\text{s}^{-1} \), liver: \( 1.66 \times 10^6 \text{ kg m}^{-2}\text{s}^{-1} \) compared with water: \( 1.48 \times 10^6 \text{ kg m}^{-2}\text{s}^{-1} \)) presents too great a barrier to the transmission of sound energy (Hoskins et al. 2010); this is also the rationale behind the use of a couplant gel between the transducer and the skin (Rose and Goldberg 1979). No meaningful echoes can be detected from beyond this type of
Figure 20. A. Waves passing across a specular reflector. a) Incident wave from the transducer. b) Wave transmitted across the interface. c) Reflected wave. B: The amplitude reflection coefficient is calculated from the change in impedance across the interface. Modified from Hoskins et al. (2010).
interface, so no image may be constructed (Hoskins et al. 2010).

An added complication of using ultrasound around air pockets is the creation of artefacts, such as reverberations that create mirror images (Fig. 21) (Rose and Goldberg 1979). This can be a source of confusion and inaccuracy when scanning.

5.4.2 Alternate windows

When it became apparent that ultrasound scanning of the SVC/RA junction through the intercostal spaces was not possible, insonation was unsuccessfully attempted through other windows: the root of the neck above the jugular notch; the liver in the subcostal angle; and the spleen. The latter required the patient to lie in the lateral decubitus position, making it inappropriate for this study. Use of the liver and jugular notch was unsuccessful due to the effect of sound wave attenuation and difficulties in manoeuvring the transducer.

5.4.2.1 Attenuation

As ultrasound waves pass through a material, they gradually lose energy and the signal becomes weaker with increasing distance. This means that the depth that the waves can penetrate (and therefore the depth to which ultrasound can be used for imaging) is limited. This effect, called attenuation, is measured in decibels per centimetre per megahertz (dB cm⁻¹ MHz⁻¹), and is caused primarily by absorption: transformation of sound energy to heat in the body tissues. Absorption increases with increasing sound wave frequency and with increasing collagen and fat content of the tissue being insonated (Duck 2008; Hoskins et al. 2010), so while higher frequencies afford greater resolution, they cannot penetrate as deeply into the tissues (Hoskins et al. 2010).
Figure 21. Duplex image demonstrating reverberation artefact. The author’s internal thoracic artery (A) is shown alongside its mirror image (B).
5.4.2.2 Alternate transducers

The P10-4 transducer proved inadequate as it could not generate ultrasound frequencies low enough to penetrate as deeply as required. Insonation was attempted with a CH4-1 (4–1MHz) curved linear transducer (Siemens AG, Erlangen, Germany). However, the large size of the transducer head (“footprint”) led to difficulties manoeuvring it around the jugular notch and subcostal angle, so the SVC/RA junction was not visualised. Two phased array cardiac transducers (PST-25BT; PST-30BT) were then trialled on a Toshiba Aplio XG ultrasound system (Toshiba America Medical Systems, Inc., Tustin, CA, USA). These transducers had small footprints for easier manoeuvrability while still producing low frequency ultrasound for greater penetration. Cardiac chambers could be seen through the liver and the brachiocephalic veins from above the jugular notch, but once again the SVC/RA junction could not be insonated (Fig. 19). Penetration remained inadequate, manoeuvrability around the neck remained poor and the costal margin adjacent to the liver obstructed the view of the site of interest.

5.4.3 Alternate breathing techniques

A potential solution to the problem of lung tissue in the costomediastinal recess could have been to ask participants to exhale maximally and hold their breath while the SVC/RA junction was identified through the intercostal spaces. This may have emptied the recess of enough lung tissue to see the junction with ultrasound. However, this technique may have altered its position, which would mean the results of the study could not be reliably applied to the general population in normal respiration. This technique was therefore not attempted.
5.4.4 Transoesophageal echocardiography (TOE)

Another possible way of achieving our aim would have been to use transoesophageal echocardiography (TOE). The SVC/RA junction could have been easily visualised using this method, though penetration of the beam may not have been sufficient to relate the junction to the thoracic cage directly. Moreover, TOE requires a different level of expertise and is much more invasive than percutaneous ultrasound. Consequently, TOE was not considered as an alternative method; its logistic difficulties and the need for new ethical and consent considerations precluded its use.

5.4.5 Future directions

Further research is needed regarding the position of the SVC/RA junction in living individuals. As previously stated, only one such study has been undertaken (Hsu et al. 2007) which had only twenty participants and did not examine changes in this surface marking with posture or respiration. It is possible that the SVC/RA junction is affected by respiration in a similar way to the tracheal bifurcation (albeit not to such an extent); the tracheal bifurcation moves up to two vertebral levels inferiorly during deep inspiration (Standring 2008). If this is the case, the position of the catheter tip within the superior vena cava may therefore vary during respiration or indeed with posture, and this might well affect clinical outcomes.

5.4 Conclusion

The SVC/RA junction could not be located with percutaneous ultrasound due to the presence of lung tissue between it and the thoracic wall, and the problems of beam penetration and transducer manœuvrability. Numerous alternative strategies were considered but also proved unsuccessful. Further investigation of this surface marking with other modern imaging techniques
is needed so clinicians may be better informed, thereby hopefully minimising the incidence of the potentially life-threatening complications associated with central venous catheterisation.
6 Discussion

6.1 Human projectional surface anatomy

Accurate surface anatomy is an essential part of safe clinical practice. While modern imaging techniques such as ultrasound, CT and MRI are an invaluable aid to diagnosis and intervention, they have by no means supplanted physical examination and the knowledge of surface anatomy integral to this (Varghese and Horwitz 2009). Furthermore, in some situations, these imaging modalities may not be available, such as in smaller rural clinics or the ‘third world,’ further emphasising the importance of an accurate knowledge of surface anatomy.

However, surface anatomy risks being regarded as obsolete unless it is evidence based and accurate. Our knowledge of this subject has traditionally been derived primarily from cadaver studies with the associated limitations of distortion from embalming, co-morbidity, body position and age-related changes. As such, human projectional surface anatomy often lacks a modern evidence base. In the age of evidence based practice, this is an issue that must be resolved. We simply must not practice using out-dated information.
6.2 Main findings

6.2.1 Surface anatomy reporting in contemporary reference texts

An examination of surface anatomy reporting in contemporary anatomical reference texts showed surprising levels of inconsistency between, and even within, texts (chapter 2). Whilst many surface markings such as the supracristal plane and the formation of the superior vena cava are generally agreed on, there are major discrepancies for others such as the femoral artery in the groin (authors differ on whether it is sited at the mid-inguinal point or the midpoint of the inguinal ligament), and the anterior projection of the domes of the diaphragm. There are also minor discrepancies such as the vertebral level of the aortic and tracheal bifurcations.

Additionally, many authors also disregard normal variation between individuals, as well as age-related changes, gender differences, and potential variation with BMI. Gray's Anatomy (Standring 2008) is the most comprehensive in this respect.

Finally, the three clinical examination texts examined contained relatively little surface anatomy. Surface markings such as those for the central veins and structures at the level of the sternal angle were absent in all three texts; this is a point of concern, given the important role of surface anatomy in physical examination.

6.2.2 Reappraising central venous surface anatomy with CT

The variation between texts seen in chapter 2 underlines the need for a critical evaluation of human projectional surface anatomy. To this end, the surface markings of the central veins and cardiac apex were examined using
CT (chapter 3). It was found that while the surface markings for the cardiac apex and formation of the brachiocephalic veins were consistent with what was generally reported in anatomical reference texts, other surface markings differed. On average, the site of formation of the superior vena cava and the junction of the superior vena cava and right atrium were one rib lower than frequently reported, and the azygos vein joined the superior vena cava 2 cm (approximately one vertebral level) lower than generally stated. Significant variation was noted between normal individuals, and associations with age, gender and body habitus were detected.

The differences between these results and the surface markings reported in chapter 2 illustrate the need for a body-wide reappraisal of human projectional surface anatomy. If surface anatomy is without an evidence base, students and clinicians may be learning and practicing with inaccurate information of human anatomy. Without revision in the light of modern imaging techniques, surface anatomy risks becoming obsolete.

6.2.3 Surface anatomy of the subclavian veins

In order to further characterise the surface anatomy of the central veins, the subclavian vein was examined using ultrasound. While several small studies have been undertaken regarding the relationship between the subclavian vein and the clavicle and its moderation by body position, there is no consensus regarding optimal body position in the context of subclavian vein catheterisation. Furthermore, there are almost no data on the influence of age, gender or body habitus.

The results from this study showed that the subclavian vein is closest to the clavicle at a point 6.5 ± 1 cm from the midpoint of the jugular notch in females, and 1 cm more laterally in males. This equates approximately to
the junction of the medial and middle thirds of the clavicle in both genders. At this point, its upper border lies approximately 9 mm posteroinferior to the upper border of the clavicle, and it has a diameter of approximately 10.5 mm bilaterally. Passive shoulder retraction tends to slightly decrease the size of the subclavian vein, theoretically making it more difficult to puncture. Therefore, subclavian vein catheters are probably best inserted without passive shoulder retraction and with gender differences taken into account. This may improve the rate of successful catheterisation and minimise the risk of serious complications.

A similar sonographic investigation was attempted, with the aim of reappraising the surface anatomy of the junction of the superior vena cava and right atrium. However, despite numerous attempts, this was unsuccessful due to technical limitations of surface ultrasound at this site.

6.3 Limitations

The two studies presented in this thesis involving human participants were limited in part by sample size. While larger study populations would have afforded greater statistical power, increasing population size was not feasible due to the time-consuming nature of the investigations. However, 103 participants for the CT reappraisal of central vein surface anatomy and 50 participants for the sonographic investigation of the subclavian vein were sufficient for the purposes described here.

A lack of data regarding BMI was a limiting factor in the CT reappraisal of central venous surface anatomy. While significant associations were detected between BMI and several central vein surface markings, it is difficult to reliably quantify variation with habitus with as few as 11 subjects in each BMI group.
Use of ultrasound as an imaging technique also had limitations. The clavicle casts a long acoustic shadow, partially obscuring the subclavian vein. Also, adipose tissue causes significant attenuation of ultrasound waves, which caused difficulties in visualising the subclavian vein in obese participants. However, these did not detract from the accuracy of the overall results and ultrasound was considered an appropriate imaging technique in this study.

6.4 Future directions

The research presented in this thesis illustrates the importance of reappraising human projectional surface anatomy in the light of modern imaging techniques that can be used in vivo. This work needs to be extended to include other thoracic surface markings such as the lower border of the lungs and structures at the level of the sternal angle. Similar research should also be undertaken on the abdomen and pelvis, and the surface anatomy of the head and neck.

In regards to the surface anatomy of the subclavian vein, further research is required to investigate the effect of turning the head to the contralateral side. As discussed in chapter 4, two radiological studies by Land (1971, 1972) have specifically examined the effect of turning the head. However, these studies used contrast venography which provides very little information on the three-dimensional spatial relations of the vein. Further examination should be undertaken with an imaging technique that affords greater detail, such as ultrasound or CT.
6.5 Conclusions

This thesis presents evidence based surface markings for the central veins. These are especially important in the context of central venous catheterisation. Some surface markings, such as those for the formation of the brachiocephalic veins (and the cardiac apex), are consistent with those reported in most anatomy reference texts. However, others differ markedly from the commonly accepted surface markings. A relatively wide range of variation is evident between normal individuals, and age, gender and body habitus have been shown to influence central vein surface anatomy.

The surface anatomy of the subclavian vein has also been examined. Results show that passive shoulder retraction may impede successful vein puncture, increasing the risk of potentially serious complications. Knowledge of anatomical differences between genders may be helpful in minimising the incidence of complications.

Surface anatomy is unlikely to be completely superseded by medical imaging. As an integral component of physical examination, knowledge of this subject is essential for safe clinical practice. This thesis addresses the longstanding lack of modern evidence in surface anatomy, but there is still much work to be done. A body-wide reappraisal in living subjects using modern imaging techniques is required in order for human projectional surface anatomy to be brought into the modern era.
References


Page numbers not included for texts consulted for surface anatomy because these are too numerous to document


Chakares DW, de Vocht F (2005) Static magnetic field effects on human subjects related to magnetic resonance imaging systems *Progress in Biophysics and Molecular Biology*, 87, 255-265


Chukwuemeka A, Currie L, Ellis H (1997) CT anatomy of the mediastinal structures at the level of the manubriosternal angle. Clinical Anatomy, 10, 405-408

Cobb RJ (1948) Outline for the study of scoliosis. American Academy of Orthopaedic Surgeons Instructional Course Lectures, 5, 261-275


Duck FA (2008) Hazards, risks and safety of diagnostic ultrasound. Medical Engineering and Physics, 30, 1338-1348


Gray H (1858) *Anatomy: Descriptive and Surgical*. John W. Parker, London, pp 365, 384, 420, 595


Kawano M, Yoshimine K (2007) Ultrasound observation of the subclavian vein: changes in the diameter with the head tilted down. *Journal of Anesthesia*, 21, 448


Land RE (1971) Anatomic relationships of the right subclavian vein. *Archives of Surgery*, 102, 178-180

Land RE (1972) The relationship of the left subclavian vein to the clavicle. *Journal of Thoracic and Cardiovascular Surgery*, 63, 564-568

Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics*. 33, 159-174


McMenamin PG (2008) Body painting as a tool in clinical anatomy teaching. Anatomical Sciences Education, 1, 139-144


105


Render CA (1996) The reproducibility of the iliac crest as a marker of lumbar spine level. Anaesthesia, 51, 1070-1071


Windle BCA (1896) *A handbook of surface anatomy and landmarks (2nd Ed.)*. H.K. Lewis, London
APPENDIX A

ORIGINAL REVIEW ARTICLE
REVIEW

Inconsistencies in Surface Anatomy: The Need for an Evidence-Based Reappraisal

SAMUEL J. M. HALE, S. ALI MIRJALILI, AND MARK D. STRINGER*  
Department of Anatomy and Structural Biology, Otago School of Medical Sciences, University of Otago, Dunedin, New Zealand

Accurate surface anatomy is a key component of safe clinical practice. But how consistent are modern clinical and surface anatomy texts in their reporting of common surface anatomy landmarks? Thirteen popular texts in common use were analyzed in detail: one clinical and anatomical reference text; seven clinical anatomy texts; two surface anatomy texts; and three clinical examination texts. Content relating to surface anatomy was reviewed, summarized, and assessed for consistency. Four main findings emerged: (i) there are numerous inconsistencies in clinically important surface markings (e.g., the femoral artery in the groin, superficial and deep inguinal rings, and accessory nerve in the posterior triangle), including inconsistencies within some texts; (ii) there is a consensus on many surface markings, e.g., the spleen and termination of the spinal cord; (iii) few texts address variation in surface anatomy related to age, sex, body mass, posture, respiration, and ethnicity; and (iv) the three standard clinical examination texts included in this review contain comparatively little surface anatomy. Seven surface anatomy landmarks were redefined within an evidence-based framework: termination of the spinal cord, supracrystal plane, base of the appendix, renal length, the deep inguinal ring, the femoral artery in the groin, and the accessory nerve in the posterior triangle of the neck. An evidence-based framework is essential if surface anatomy is to be accurate and clinically relevant. Clin. Anat. 23:922–930, 2010. © 2010 Wiley-Liss, Inc.

Key words: surface anatomy; surface markings; evidence-based research

INTRODUCTION

Surface anatomy is a core component of human anatomy essential to safe clinical practice. Our current understanding of the topic is largely derived from cadaver studies, with all the limitations of distortion from embalming, positioning, age, and comorbidity, and from radiographic investigations. In the last two decades, numerous studies have critically evaluated traditional surface landmarks in living subjects using modern imaging techniques such as computerized tomography (Chukwuruka et al., 1997; Glodny et al., 2009), magnetic resonance imaging (MRI) (Kim et al., 2003; Soleiman et al., 2005), and ultrasound scanning (Emanian et al., 1993). The primary aim of this study was to determine the extent to which modern clinical anatomy texts are consistent in their reporting of common surface markings. In addition, we sought to determine whether these landmarks are included in standard undergraduate texts of clinical examination and, if so, whether they too are reported consistently.

METHODS

Thirteen popular texts in common widespread use were analyzed in detail (Table 1): one clinical and anatomical reference text (A1); seven clinical anatomy

*Correspondence to: M.D. Stringer, Department of Anatomy and Structural Biology, Otago School of Medical Sciences, University of Otago, PO Box 913, Dunedin, New Zealand.  
E-mail: mark.stringer@anatomy.otago.ac.nz  
Received 21 June 2010; Accepted 28 June 2010  
Published online 9 September 2010 in Wiley Online Library  
(wileyonlinelibrary.com); DOI 10.1002/ca.21044

© 2010 Wiley-Liss, Inc.
TABLE 1. Surface Anatomical Features and Reviewed Texts

<table>
<thead>
<tr>
<th>Region</th>
<th>Surface anatomical structure</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thorax</td>
<td>Sternal angle, xiphisternal joint; cardiac surface anatomy (apex beat, heart borders, valve radiations); central venous anatomy; pleura, lungs, diaphragm; female breast, male nipple</td>
<td>Clinical and anatomical reference A1, Standing (2008)</td>
</tr>
<tr>
<td>Abdomen and pelvis</td>
<td>Transpyloric, subcostal, and supraclavicular planes; aorta (and visceral branches), inferior vena cava; gastrointestinal tract (cardia, duodenoscopic flexure, vermilliform appendix, gallbladder fundus); spleen, kidneys, ureters; superficial and deep inguinal rings; diaphragm apertures; pubic crest</td>
<td>Clinical anatomy CA1, Moore et al. (2010) CA2, Drake et al. (2010) CA3, Sinnathamby (2006) CA4, McMinn (1998) CA5, Rosse and Gaddum-Rosse (1997) CA6, Ellis and Mahadevan (2010) CA7, Abrahams et al. (2005)</td>
</tr>
<tr>
<td>Lower limb</td>
<td>Sciatic nerve, sural nerve; femoral artery (in groin), femoral triangle; great saphenous vein</td>
<td>Surface anatomy SA1, Lumley (2008) SA2, Field and Hutchinson (2006)</td>
</tr>
<tr>
<td>Head and neck</td>
<td>Central sulcus, pterion; hard palate, hyoid bone; carotid bifurcation; accessory nerve; plane of C6 vertebra; parotid duct</td>
<td>Clinical examination E1, Bickley and Szilegyi (2009) E2, Douglas et al. (2009) E3, Talley and O’Connor (2010)</td>
</tr>
<tr>
<td>Vertebral column</td>
<td>Spinal cord and dural sac termination; sacral dimples</td>
<td></td>
</tr>
</tbody>
</table>

texts (CA1–7); two surface anatomy texts (SA1–2); and three clinical examination texts (E1–3). All texts were searched for descriptions of adult surface anatomy relating to the structures listed in Table 1 (Fig. 1). Descriptions were transcribed verbatim into a spreadsheet (S.J.M.H.), and most entries were checked independently (A.M.) to ensure completeness and accuracy. These data were then reviewed, summarized, and assessed for consistency (S.J.M.H.). Conventional shorthand is used to express vertebral levels, i.e., C = cervical, T = thoracic, L = lumbar, and S = sacral, with L4/S indicating the intervertebral disc between the fourth and fifth lumbar vertebrae.

RESULTS

Thorax

Sternal angle. The horizontal plane of the sternal angle is level with the second costal cartilage anteriorly and generally stated to extend from the junction of T4/S or the lower border of T4 posteriorly. Most clinical anatomy texts also mention that this plane marks the division of the superior and inferior mediastinum, the bifurcation of the trachea, the origin and termination of the aortic arch, the level at which the azygos vein enters the superior vena cava, the approximate level at which the thoracic duct crosses to the left side of the posterior mediastinum, the superior limit of the pericardium, and the site at which the right and left parietal pleura come into contact anteriorly. The sternal angle receives little attention in the clinical examination texts, which simply state that it is level with the second costal cartilage anteriorly; only one of these texts mentions the tracheal bifurcation and arch of aorta (E1).

Some inconsistencies are apparent. One text states that the level of the tracheal bifurcation is at the upper border of T5 in one section and T4 in another (A1). Only a few texts comment on variation with respiration (A1, CA1, CA3, CA4, CA5, and CA6), posture, and build (CA1 and CA5). One clinical anatomy text describes the pulmonary arteries originating at the level of the sternal angle (CA1) and another at an even higher plane (CA5).

The vertebral level of the xiphisternal joint is generally agreed to be about T9, but minor variations exist, e.g., lower border of T8 (CA2, CA3, and CA4) and T10 (CA5). A few texts do not give a vertebral level (SA2, CA7, and E1–3).

Cardiac anatomy. The heart borders are well described in A1, which documents their general position as clockwise from the left second costal cartilage 1 cm from the sternum edge, to the apex of the heart in the left fifth intercostal space near the midclavicular line, to the right sixth costal cartilage 1–2 cm lateral to the sternal edge, and to the right third costal cartilage. This text also emphasizes variation with age, sex, stature, build (obesity), ventilation, and posture. Only minor differences are found in other texts, e.g., left second intercostal space for the upper left border of the heart. However, two texts document only one of these landmarks (CA3 and CA7), two show approximate borders in a diagram (E2 and E3), and one fails to mention the position of the apex (CA7).

Sites of auscultation for optimum detection of cardiac valve murmurs are mostly consistent but are omitted in two texts (CA6 and SA2). Tricuspid valve murmurs are generally reported to be heard best in the fifth intercostal space at the lower left sternal edge, but some texts suggest that these murmurs are heard best over the lower sternum in the midline (CA3, CA4, and CA5) or over the right fourth costal cartilage (SA1).

Central venous anatomy. Most anatomy texts refer to the formation of the brachiocephalic veins behind the sternoclavicular joints or sternal end of the clavicles, their union to form the superior vena
cava posterior to the right first costal cartilage, and the entry of the superior vena cava into the right atrium behind the right third costal cartilage. Notable discrepancies are the formation of the superior vena cava behind the right first rib (CA9) or at the level of the sternal angle (SA1). These landmarks are not documented in the clinical examination texts.

**Pleura, lungs, and diaphragm.** The surface markings of the pleura and lungs vary little between anatomical texts but are surprisingly neglected in the clinical examination texts, where, at most, they are indicated by a rough diagram. The dome of cervical pleura and apex of lung are typically described as 2.5 cm above the medial third of the clavicle, but some texts state that this point is the junction of the medial and middle thirds of the clavicle (CA3 and CA6), one text has both of these landmarks (A1), and another mentions the medial third of the clavicle and the midpoint in different sections (CA7). Only a few texts emphasize that the pleura extends just below the 12th rib at its medial extremity (CA3-CA7).

One major inconsistency is the level of the anterior projection of the dome of the hemidiaphragm after maximum expiration. This is variably stated to be level with the fourth costal cartilage on the right and one rib lower on the left (A1 and SA2), the fourth intercostal space or fifth rib on the right and fifth rib or fifth intercostal space on the left (CA2-CA5 and SA1), or even the fourth intercostal space (CA1) or sixth costal cartilage (E3) bilaterally but with the right dome higher than the left. Some texts offer no surface marking (CA6, CA7, and E1). Variation in the position of the dome of the diaphragm with respiration, posture, and build is mentioned in only a few texts.

**Breast and nipple.** There are only minor discrepancies in the surface anatomy of the female breast but it is not mentioned in some texts (SA2, E2, and E3). The male nipple is sited in the fourth intercostal space in the midclavicular line in most anatomy texts.

**Abdomen and Pelvis.**

**Transpyloric plane.** Although this is defined as lying midway between the suprapubic notch and the upper border of the pubic symphysis, several texts approximate this to midway between the xiphisternal joint and the umbilicus either exclusively (CA7 and SA1) or additionally (CA2, CA3, and CA4). The clinical examination texts do not specifically mention the transpyloric plane.

The transpyloric plane is generally described as lying at the lower border of LI intersecting with the following abdominal structures: the pyloric orifice just to the right of the midline (in supine position with an empty stomach), the fundus of the gallbladder, the tip of the ninth costal cartilage (where the costal margin is crossed by the linea semilunaris), the hilum of both kidneys (right lower than left), the origin of the superior mesenteric artery, and the neck of the pancreas anterior to the first part of the portal vein. Notable deviations to this description are as follows: the origin of the superior mesenteric artery which in one text is stated to lie in the plane and also above it (A1); the eighth costal cartilage (CA1); the duodenojejunal flexure (CA6); and the pancreatic duct emptying into the second part of the duodenum (SA2).

**Subcostal plane.** This horizontal plane joining the lowest points of the costal margins is typically described as intersecting the body of L3 and the tenth costal cartilage with the third part of the duodenum and the origin of the inferior mesenteric artery at this level (A1 and CA6). Some anatomy texts do not specify a vertebral level (CA1, CA3, and CA4), and one surface anatomy text (SA2) and all three clinical examination texts do not mention this plane.

**Supracristal plane.** This horizontal plane between the tops of the iliac crests passes through the body of L4 or the L4/5 intervertebral disc. It is also referred to as the "intercristal" line (SA1) or, in
one text (CA6), as the "supracristal" line and the "transcrystal" plane (CA6). This landmark is only referred to in one clinical examination text (E1).

**Bifurcation of abdominal aorta.** Most texts state that the abdominal aorta bifurcates at the lower border of L4 just to the left of the midline; this is about 2 cm below and to the left of the umbilicus in the supracristal plane. One text erroneously refers to this as the transcrubicular plane in one section (A1), whereas others place the bifurcation at the level of the umbilicus (SA1 and E2) or 2.5 cm below the umbilicus in the supracristal plane. Several texts document the deep ring as being about 1 cm above the umbilical point (A1, CA2, CA5, CA6, and E2), whereas a similar-numbered text describes it as about 1 cm below the umbilical point (CA1, CA3, CA4, CA7, SA1, E1, and E3).

**Gastroesophageal junction (cardia).** Several texts state that this is to the left of the midline at the level of the left seventh costal cartilage and/or T11 (A1, CA1, CA2, CA5, and SA2). One text cites T10 (CA4) and a later edition of the same text as T10 and T11 in different sections (CA3). Many texts do not give a surface marking for this junction.

**Duodenjejunal flexure.** The clinical and surface anatomy texts position the flexure to the left of L2, but there are minor discrepancies in two texts (CA1 and CA6), which state that the flexure lies to the left of L2 but also mention it lying in the transpyloric plane (given as L3). One surface anatomy text (SA1) puts the flexure in the subcostal plane (given as the lower border of L3). The clinical examination texts omit this landmark.

**Arteries to the gut and kidneys.** In anatomy texts, the origin of the celiac trunk, superior mesenteric artery, and inferior mesenteric artery are consistently given as T12 (or upper border L1 in CA2), L1 or L1/2, and L3, respectively. A1 states that the origin of the superior mesenteric artery is at the level of L1/2 and also "usually lies below the level of the transpyloric plane" (given as lower border of L1). Clinical examination texts do not detail these levels. The renal arteries, when single, are described as arising from the abdominal aorta at L1/2 or L2 (A1, CA2, and CA5). One anatomy text indicates that the pubic tubercle marks the vesicoureteric junction (A1). The course
of the ureter on a plain radiograph is probably more important and is mentioned in four texts (CA3, CA4, CA6, and CA7). The clinical examination and surface anatomy texts contain no relevant information.

Plane of pubic crest. According to two sources (CA3 and CA4), the upper border of the pubic symphysis lies on a plane with the ischial spine, the tip of the coccyx, the centre of the acetabulum and femoral head, and the apex of the greater trochanter. Other anatomy texts indicate that this plane intersects: the inferior surcram or coccyx (depending on the degree of lumbar lordosis and sacral tilt) (A1); the centre of the femoral head and tip of greater trochanter (CA1); the greater trochanter (SA2 and E1); and the ischial spine, centre of acetabulum, and, in women, the tip of the coccyx (CA5). The plane is not described in several texts (CA2, CA6, CA7, SA1, E2, and E3).

Lower Limb

Femoral artery. Most texts state that the femoral artery is located at the midinguinal point (A1, CA3, CA4, CA5, CA6, CA7, SA1, E1, and E2). However, two clinical anatomy texts (CA1 and CA2) refer not only to this landmark but also to the midpoint of the inguinal ligament. One clinical examination text (E3) describes the femoral pulse as being situated below the inguinal ligament, one-third of the way up from the pubic tubercle.

Great saphenous vein. The site of the saphenous opening (saphenofemoral junction) is confusing. It is stated in CA3 and CA4 to be 3.5 cm above and lateral to the pubic tubercle. However, does this mean 3 or 3.5 cm below and 3 or 3.5 cm lateral as indicated by CA1 and E2 or is a diagonal distance envisaged? Other texts, such as A1, are more specific and mention 3 cm lateral to a point 2.5 cm below the inguinal ligament. CA6 and SA2, Notable exceptions are CA5 and SA1, which place the opening 3–4 cm inferior and just lateral to the pubic tubercle. Two texts, however, give the general vicinity of the opening as just inferior to the medial end of the inguinal ligament (CA2 and CA5). There is a consensus that the great saphenous vein lies immediately anterior to the medial malleolus although this surface marking is not included in one surface anatomy text (SA1) and one clinical examination text (E3).

Femoral triangle. There is general agreement among the clinical anatomy texts that the femoral triangle is bordered by the medial borders of sartorius and adductor longus, but there is one notable exception (CA1), which reports the medial border of the femoral triangle as the lateral border of adductor longus.

Sciatic nerve. The standard description of the surface anatomy of the sciatic nerve is from (i) a point midway between the posterior superior iliac spine and the ischial tuberosity, curving laterally and inferiorly, and passing through (ii) a point midway between the ischial tuberosity and greater trochanter. From here it passes vertically downward in the midline of the posterior aspect of the thigh to the apex of the popliteal fossa (A1 and CA6). The first of these landmarks is modified in two texts to one third of the way up from the ischial tuberosity to the posterior superior iliac spine (CA3 and CA4). Other texts give only the second landmark (CA1, CA2, CA5, CA7, SA2, and E1) or less information (SA1, E2, and E3).

Sural nerve at ankle. There is agreement that the sural nerve lies below the lateral malleolus, but the surface anatomy texts and the clinical examination texts ignore this nerve.

Head and Neck

Hyoid bone and hard palate. In the few texts that mention the vertebral level of the hyoid bone (A1, CA1, CA3, CA4, CA6, and SA1), there is unanimity that this corresponds to C3. Only two texts refer to the vertebral level of the hard palate (CA3 and CA4), which is stated to be level with the anterior arch of the atlas.

Vertebral level of C6. There is a consensus that C6 corresponds to the level of the cricoid cartilage (specifically, its lower border [CA2, CA6, and SA1]) and that this marks the transition from the pharynx to esophagus, larynx to trachea, and the position of the middle cervical ganglion. Many texts point out that the vertebral artery enters the foramen transversarium and that the inferior thyroid artery can be located at this level (CA1, CA3, CA4, and CA6). The C6 landmark is not mentioned in the clinical examination texts.

Bifurcation of common carotid artery. This surface landmark is not included in the clinical examination texts, but the anatomy texts all agree on the upper border of the thyroid cartilage at C3/4 (A1 and CA2) or C4 (CA1, CA3, CA4, CA5, and CA7). Three texts highlight variability (A1, CA3, and CA4).

Accessory nerve in the posterior triangle of the neck. A1 appropriately stresses the variability of the site of emergence of the accessory nerve from the posterior border of sternocleidomastoid and offers two surface markings for the nerve in the posterior triangle: (i) a line passing from the junction between the upper and middle thirds of the posterior border of sternocleidomastoid to the junction of the middle and lower thirds of the anterior border of trapezius; and (ii) a line joining the palpable transverse process of the atlas (approximately 1 cm below the mastoid process) to the anterior border of trapezius 3–5 cm above the clavicle.

Several texts (CA2, CA5, CA7, SA2, and E1–3) give no surface marking. Others provide different landmarks for the nerve’s exit from the posterior border of sternocleidomastoid: near the middle of its posterior border (CA1, CA4, and SA1), one third of the way down or a little lower (CA3), or at the junction of the superior and middle thirds (elsewhere in CA4).

Pteryon. Only five texts give a surface marking for the pteryon overlying the anterior branch of the middle meningeal artery, and this is variable: approximately 3–4 cm above the midpoint of the zy-
gomatic bone (A1, CA1, and CA7); approximately 2.5 cm above the zygomatic arch and 2.5 cm poste-
rior to the lateral orbital margin (CA2); 3.5 cm behind the frontozygomatic suture (A1); and 3.5 cm behind and 1.5 cm above the frontozygomatic suture (CA7 and SA1).

**Central sulcus.** A surface landmark for the cen-
tral sulcus is only stated in one clinical anatomy text
(C6), which describes a line angled downward and
forward from a point 1 cm behind the midpoint
between the nasion and inion. Ca5 briefly refers to
the upper end of the sulcus only.

**Parotid duct.** In the clinical anatomy texts sup-
plying a surface marking for the duct, it is variably
given as: the middle third of a line from the lower
border of the tragus of the auricle to the midpoint
of the philtrum of the upper lip (A1); over the mas-
teter a finger’s breadth below the zygomatic arch, along a
line between the intertragic notch of the auricle and
the midpoint of the philtrum (CA3 and CA4); emerg-
ing from the parotid gland midway between the zy-
gomatic arch and corner of mouth (A1 and CA2); or
running almost horizontally forward across the mass-
ester at about the level of the tip of the lobule of the
ear (CA5).

**Vertebral column**

**Termination of spinal cord and dural sac.** There is a consensus that the spinal cord terminates
at the level of L1, L1/2, or L2 and that the dural sac
ends at S2. Only a few texts emphasize variation in
the level at which the spinal cord terminates (A1,
CA2, and CA6). Only one clinical examination text
gives a surface marking for the termination of the
spinal cord (E1) and none document the termination
of the dural sac.

**Sacral dimples.** There is agreement that the sac-
ral dimple overlies the posterior superior iliac spine
and the middle of the sacroiliac joint and that the
plane between these two intersects the spinous pro-
cess and body of S2 (A1, CA1, CA2, CA3, CA4, CA5,
CA7, and E1). One surface anatomy text places the
sacroiliac joint 1 cm lateral to the posterior superior
iliac spine (SA2) and one mentions the dimple but
ignores these include major discrepancies (e.g.,
the femoral artery in the groin, superficial and deep in-
guinal rings, accessory nerve in the posterior trian-
gle, pteryion, and the appendix primary site of the
spleen), and minor but potentially signifi-
cant inconsistencies (e.g., the bifurcation of the ab-
dominal aorta, transpyloric plane, base of appendix,
renal dimensions and surface anatomy, and the level of
the tracheal bifurcation). Surprisingly, there are
also inconsistencies within texts. Second, there is a
consensus on many surface markings such as the
spine, termination of the spinal cord and dural sac,
structures at the level of C6, the sural nerve at the
ankle, and the female breast. Third, few texts men-
tion variation in surface anatomy related to age, sex,
body mass (particularly obesity), posture, respira-
tion, and ethnicity. Gray’s Anatomy is the most com-
prehensive in this context. Finally, the three stand-
ear clinical examination texts included in this review
contain comparatively little surface anatomy and
omit aspects such as central venous anatomy, gas-
trointestinal landmarks, the ureters, bifurcation of
the common carotid artery, and the relevance of C6.

Is surface anatomy neglected in modern texts of
clinical examination because it has limited clinical
utility or has been superseded by modern noninva-
sive imaging techniques? This may be particularly
true for the deeper projectional surface anatomy of
thoracic and abdominal viscera exemplified by the
sternal angle, transpyloric, and subcostal planes.
However, clinical examination, which involves a
knowledge of surface anatomy, has not been sup-
planted by technology (Verghese and Horwitz,
2009). Access to imaging technology is variable, and
a structure like the femoral artery needs to be
located accurately, reliably, and sometimes prompt
ly in everyday clinical practice. In addition, surface
anatomy is not just about clinical examination but
may provide convenient reference points for the sur-
geon (e.g., sitting incision lines on an extremity
are an approximate vertebral level of an artery) and is
almost certainly of value in helping students learn
human anatomy as shown by the success of body
painting as a learning tool (McMenamin, 2008).

**DISCUSSION**

All of the texts reviewed in this study have their
individual strengths and particular target readership.
The purpose of our study was not to criticize these
successful books, but to highlight inconsistencies in
standard surface anatomy and the need for an evi-
dence-based reappraisal of this topic. We have
attempted to minimize errors by using two research-
ers to independently review data at all stages of the
study.

This study demonstrates four important points
about surface anatomy as presented in popular con-
temporary texts of clinical and surface anatomy and
clinical examination. First, there are numerous
inconsistencies in clinically important surface mark-
ings. These include major discrepancies (e.g.,
the femoral artery in the groin, superficial and deep in-
guinal rings, accessory nerve in the posterior trian-
gle, pteryion, and the appendix primary site of the
spleen), and minor but potentially signifi-
cant inconsistencies (e.g., the bifurcation of the ab-
dominal aorta, transpyloric plane, base of appendix,
renal dimensions and surface anatomy, and the level of
the tracheal bifurcation). Surprisingly, there are
also inconsistencies within texts. Second, there is a
consensus on many surface markings such as the
spine, termination of the spinal cord and dural sac,
structures at the level of C6, the sural nerve at the
ankle, and the female breast. Third, few texts men-
tion variation in surface anatomy related to age, sex,
body mass (particularly obesity), posture, respira-
tion, and ethnicity. Gray’s Anatomy is the most com-
prehensive in this context. Finally, the three stand-
ear clinical examination texts included in this review
contain comparatively little surface anatomy and
omit aspects such as central venous anatomy, gas-
trointestinal landmarks, the ureters, bifurcation of
the common carotid artery, and the relevance of C6.

**Termination of Spinal Cord**

Large MRI studies of European (Safuddin et al.,
1998; Macdonald et al., 1999; Soleiman et al.,
2005) and Korean (Kim et al., 2003) adults have consistently shown that, in the supine position, the spinal cord terminates between T11 and L3 but in 80-90% of adults this point is between the upper border of L1 and the lower border of L2. The latter was also confirmed in a recent study of 112 adult cadavers in Kenya (Gatonga et al., 2010). Two of these studies also found that the dural sac terminates at S2 in about two thirds of individuals but may be higher or lower (Macdonald et al., 1999; Soliman et al., 2005).

**Evidence-based recommendation:** the spinal cord in adults terminates between T11 and L3 but in most cases this point lies between the upper border of L1 and the lower border of L2.

### Supracristal Plane

The supracristal or intercrystal plane is frequently used as a guide for lumbar puncture, spinal injection, and for siting incisions in patients undergoing spinal surgery (Walsh et al., 2006). A radiographic study in 450 European adult patients showed that the line crossed the body of L4 or the L4/5 intervertebral disc in 72% of cases (Walsh et al., 2006). These findings support a previous radiographic study of 163 patients in which the figure was 79% (Render, 1996) and are similar to subsequent smaller radiographic studies of European (Chakraverty et al., 2007) and American (McLaughlin et al., 2007) adults, and a dissection study of African cadavers (Gatonga et al., 2010). The equivalent figure determined by radiography in 72 Korean adults was 64% (Kim et al., 2007), but it is difficult to know whether this is a true ethnic difference.

Several studies have shown that the supracristal plane determined by palpation tends to identify a higher vertebral level than the radiographic level in as many as 77% of cases (Broadbent et al., 2000; Chakraverty et al., 2007; Levins, 1991; Kim et al., 2007; Van Gessel et al., 1993). This is more likely in women and in patients with a higher body mass index in whom the supracristal plane is most likely to identify the L3/4 intervertebral space (Chakraverty et al., 2007).

**Evidence-based recommendation:** the supracristal plane crosses the body of L4 or the L4/5 intervertebral disc in most adults. Palpation tends to identify the L3/4 disc space, particularly in women and overweight patients.

### Base of the Appendix

McBurney’s point should be abandoned as a useful surface landmark for the base of the appendix. Ignoring the fact that McBurney actually described the point of maximum tenderness in acute appendicitis and not the surface anatomy of the base of the appendix (Karim et al., 1990), several studies analyzing barium enemas in supine adults with suspected large bowel disease have shown that the base of the appendix is very variably located but rarely at McBurney’s point (Karim et al., 1990; Naraynsingh et al., 2002; Ramsden et al., 1993). Indeed, it is likely that the position of the base of the appendix varies with posture, degree of bowel distension, adiposity, etc.

**Evidence-based recommendation:** McBurney’s point is an unreliable surface landmark for the base of the appendix.

### Renal Length and Width

Although each imaging technique has limitations in precisely determining renal length in vivo, there are data for renal dimensions derived from ultrasound scanning, MRI, and computed tomography studies in relatively large numbers of European and North American adults with healthy kidneys (Cheong et al., 2007; Emanian et al., 1993; Goody et al., 2009). Each of these studies reported slightly different renal dimensions, but a useful practical guide would be a renal length of approximately 11.5 cm in men and 11 cm in women and a renal width of about 5.5 cm in both sexes. The left kidney is slightly longer than the right by a few millimeters, and there is a weak influence of stature on renal length.

**Evidence-based recommendation:** renal length in white men and women is approximately 11.5 and 11 cm, respectively.

### Deep Inguinal Ring

Although it is a surgical maxim that a direct and indirect inguinal hernia can be distinguished by digital pressure over the deep inguinal ring, the accuracy of this is doubtful (Andrews et al., 1996; Conaghan et al., 2004; Sanjay et al., 2010). Nevertheless, a clinician should know the surface landmark of the deep inguinal ring.

Numerous studies have investigated this landmark in adults (Andrews et al., 1996; Campbell, 1988; Conaghan et al., 2004; Sanjay et al., 2006) and children (Parnis et al., 1997) with inguinal hernias (predominantly males), and in cadavers without inguinal pathology (Koliyanidou et al., 2004; Scott and Willan, 1991). These studies are performed haphazardly because the definition of the deep inguinal ring varies: some studies have referenced the position of the finger in the deep ring with respect to the anterior superior iliac spine and pubic landmarks, and others refer to the centre or edge of the ring (lateral or medial). In addition, an inguinal hernia may well distort the anatomy.

Studies locating the surface marking of the deep inguinal ring in men with an inguinal hernia, each with no more than 50 patients, indicate that the deep inguinal ring in most men corresponds to a point within 1 cm of the midinguinal point (midway between the anterior superior iliac spine and the pubic symphysis) (Andrews et al., 1996; Campbell, 1988; Conaghan et al., 2004; Sanjay et al., 2006).

This definition of the surface anatomy of the deep inguinal ring is also consistent with data in both sexes from cadavers (Koliyanidou et al., 2004; Scott and Willan, 1991).

**Evidence-based recommendation:** the deep inguinal ring in most adults lies within 1 cm either side of the midinguinal point (midway between the anterior superior iliac spine and the pubic symphysis).
Femoral Artery in the Groin

It is surprising that there should be any controversy about the surface marking of such an important clinical landmark. Once again, the evidence from the literature must be considered in relation to sample size, whether the study was in living subjects or cadavers, the methodology, and the age, gender, and ethnicity of the subjects. There are no studies on the effects of obesity on the surface anatomy of the femoral artery although this certainly affects the ease with which the femoral pulse can be detected (Campbell, 1988). Cadaver studies have shown that the midinguinal point overlies the femoral artery in most cases (Koltypadn et al., 2004; Scott and Willan, 1991). There is greater variability in living subjects, but a surface landmark within 1 cm either side of the midinguinal point would account for most cases (Andrews et al., 1996; Hunt and Harris, 1996; Sandstrom et al., 2000; Stubbs and Cumberland, 1992).

The midpoint of the inguinal ligament (midway between the anterior superior iliac spine and pubic tubercle) is lateral to this surface landmark and should not be used. It is also worth noting that the inguinal skin crease lies about 6–7 cm inferior to the inguinal ligament (Lechner et al., 1988) and that the femoral artery gives off its profound femoris branch proximal to this skin crease in most cases (Grier and Hartnell, 1990; Lechner et al., 1988).

Evidence-based recommendation: the femoral artery in most adults lies immediately below the inguinal ligament within 1 cm either side of the midinguinal point (midway between the anterior superior iliac spine and the pubic symphysis).

Accessory Nerve

In a study of 25 cadavers, Symes and Ellis (2005) demonstrated that variations in the anatomy of the accessory nerve in the posterior triangle of the neck precluded an accurate working definition of its surface marking. Thus, on present evidence, there is no practical surface landmark for the accessory nerve in the posterior triangle of the neck. This is unfortunate because the accessory nerve at this site is one of the most commonly accidentally injured nerves during surgical procedures (Kreitschmer et al., 2001).

Evidence-based recommendation: There is currently no accurate surface marking for the accessory nerve in the posterior triangle of the neck.

Surface anatomy must be accurate (evidence-based) and relevant (of practical utility). If surface anatomy is not reappraised in the light of new evidence, it will rightly be perceived as being of limited clinical value and belonging to a bygone era.

ACKNOWLEDGMENTS

The authors thank Robbie McPhee, Medical illustrator and Graphic Artist, Department of Anatomy and Structural Biology, for his expert assistance with Figure 1.

REFERENCES


APPENDIX B

COMPUTERISED TOMOGRAPHIC INVESTIGATION

ETHICAL APPROVAL MĀORI CONSULTATION
11 December 2009

Dr Mark Stringer
Department of Anatomy and Structural Biology
Dept. of Anatomy and Structural Biology
Otago School of Medical Sciences
University of Otago
PO Box 913, Dunedin

Dear Dr Stringer

Ethics ref: LRS/09/30/EXP
Study title: A critical reappraisal of human surface anatomy
Investigators: Dr Mark Stringer, Seyed Ali Mirjalili, Sam Hale, Prof Tim Buckenham

The above study has been given ethical approval by the Chairperson of the Lower South Regional Ethics Committee.

Certification
The Committee is satisfied that this study is not being conducted principally for the benefit of the manufacturer or distributor of the medicine or item in respect of which the trial is being carried out.

Accreditation
The Committee involved in the approval of this study is accredited by the Health Research Council and is constituted and operates in accordance with the Operational Standard for Ethics Committees, April 2006.

Progress Reports
The study is approved until 31 August 2011. The Committee will review the approved application annually and notify the Principal Investigator if it withdraws approval. It is the Principal Investigator’s responsibility to forward a progress report covering all sites prior to ethical review of the project by 16 November 2009. The report form is available on http://www.ethicscommittees.health.govt.nz. Please note that failure to provide a progress report may result in the withdrawal of ethical approval. A final report is also required at the conclusion of the study.

Requirements for SAE Reporting
The Principal Investigator will inform the Committee as soon as possible of the following:
• Any related study in another country that has stopped due to serious or unexpected adverse events
• withdrawal from the market for any reason
• all serious adverse events occurring during the study in New Zealand which result in the investigator breaking the blinding code at the time of the SAE or which result in hospitalisation or death.
• all serious adverse events occurring during the study worldwide which are considered related to the study medicine. Where there is a data safety monitoring board in place, serious adverse events occurring outside New Zealand may be reported quarterly.
All SAE reports must be signed by the Principal Investigator and include a comment on whether he/she considers there are any ethical issues relating to this study continuing due to this adverse event. It is assumed by signing the report, the Principal Investigator has undertaken to ensure that all New Zealand investigators are made aware of the event.

Amendments
All amendments to the study must be advised to the Committee prior to their implementation, except in the case where immediate implementation is required for reasons of safety. In such cases the Committee must be notified as soon as possible of the change.

Please quote the above ethics committee reference number in all correspondence.

The Principal Investigator is responsible for advising any other study sites of approvals and all other correspondence with the Ethics Committee.

It should be noted that Ethics Committee approval does not imply any resource commitment or administrative facilitation by any healthcare provider within whose facility the research is to be carried out. Where applicable, authority for this must be obtained separately from the appropriate manager within the organisation.

We wish you well with your study.

Yours sincerely

Anna Paris
Lower South Regional Ethics Committee Administrator
dd (03) 474 8562
dfax (03) 474 8090
Email: anna_paris@moh.govt.nz
NGÄI TAHU RESEARCH CONSULTATION COMMITTEE
TE KOMITI RAKAHAU EI KAI TAHU

15/12/2009 - 01
Wednesday, 16 December 2009

Professor Stringer
Anatomy & Structural Biology
Dunedin

Tēnā koe Professor Stringer

Title: A critical reappraisal of human surface anatomy.

The Ngāi Tahu Research Consultation Committee (The Committee) met on Tuesday, 15 December 2009 to discuss your research proposition.

By way of introduction, this response from the Committee is provided as part of the Memorandum of Understanding between Te Rūnanga o Ngāi Tahu and the University. In the statement of principles of the memorandum, it states "Ngāi Tahu acknowledges that the consultation process outlined in this policy provides no power of veto by Ngāi Tahu to research undertaken at the University of Otago". As such, this response is not "approval" or "mandate" for the research, rather it is a mandated response from a Ngāi Tahu appointed committee. This process is part of a number of requirements for researchers to undertake and does not cover other issues relating to ethics, including methodology; they are separate requirements with other committees, for example the Human Ethics Committee, etc.

The Committee considers the research to be of importance to Māori health.

The Committee notes that this project involves already existing data and they suggest that ethnicity data be recorded, in this study, if available.

The Committee notes the researchers have identified that, "Findings from this study would be relevant to Māori and non-Māori"; and so, the Committee suggests dissemination of the research findings to Māori health organisations regarding this study.

We wish you every success in your research and the Committee also requests a copy of the research findings.

The recommendations and suggestions above are provided on your proposal submitted through the consultation website process. These recommendations and suggestions do not necessarily relate to ethical issues with the research, including methodology. Other committees may also provide feedback in these areas.
NGĀI TAHU RESEARCH CONSULTATION COMMITTEE
TE KOMITI RAKAHAU KI KĀI TAHU

Nīhau nos, nā

Mark Brunton
Kainakawaenga Rangahau Māori
Facilitator Research Māori
Research Division
Te Whare Wānanga o Otago
Ph: +64 3 479 8738
email: mark.brunton@otago.ac.nz
Web: www.otago.ac.nz

The Ngāi Tahu Research Consultation Committee has membership from:
Te Rūnanga o Ōtākou Incorporated
Kūti Huiapapa Rūnaka ki Puketeraki
Te Rūnanga o Moeraki
APPENDIX C

COMPUTERISED TOMOGRAPHIC INVESTIGATION

RAW DATA
<table>
<thead>
<tr>
<th>Patient</th>
<th>Kyphosis (°)</th>
<th>Scoliosis (°)</th>
<th>BMI</th>
<th>Azygos vein (cm)</th>
<th>Cardiac apex (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>7.8</td>
<td>85</td>
<td>33.3</td>
<td>1.2</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 2</td>
<td>8.5</td>
<td>80</td>
<td>21.8</td>
<td>2.9</td>
<td>6.5</td>
</tr>
<tr>
<td>Patient 3</td>
<td>7.3</td>
<td>75</td>
<td>23.0</td>
<td>1.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 4</td>
<td>6.9</td>
<td>82</td>
<td>42.9</td>
<td>2.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 5</td>
<td>7.1</td>
<td>33</td>
<td>25.0</td>
<td>1.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 6</td>
<td>6.5</td>
<td>85</td>
<td>21.0</td>
<td>3.2</td>
<td>6.5</td>
</tr>
<tr>
<td>Patient 7</td>
<td>7.4</td>
<td>27.4</td>
<td>28.1</td>
<td>2.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 8</td>
<td>7.2</td>
<td>21.7</td>
<td>21.7</td>
<td>1.2</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 9</td>
<td>7.6</td>
<td>23.1</td>
<td>23.1</td>
<td>3.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Patient 10</td>
<td>7.9</td>
<td>27.7</td>
<td>27.7</td>
<td>2.5</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Notes:
- M: Male
- F: Female
- Caucasian

Azygos vein sternal angle (°)

Cardiac apex vertebral level (CC/ICS)

Ventral level

Lateral formation

R BCV

SVC/RA
<table>
<thead>
<tr>
<th>Subject</th>
<th>Notes</th>
<th>Age</th>
<th>Gender</th>
<th>Ethnicity</th>
<th>Height</th>
<th>Weight</th>
<th>BMI</th>
<th>Cardiac apex (CC/ICS)</th>
<th>SVC formation (CC/ICS)</th>
<th>L SVC</th>
<th>R SVC</th>
<th>R SVC</th>
<th>azygos vein (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>33</td>
<td>M</td>
<td>Caucasian</td>
<td>170</td>
<td>64</td>
<td>23.4</td>
<td>4.5</td>
<td>4</td>
<td>3.4</td>
<td>3.6</td>
<td>3.4</td>
<td>1.9</td>
</tr>
</tbody>
</table>

a Number with no decimal places signifies the upper half of the vertebral body. Number ending in .5 signifies the lower half of the vertebral body. Number ending in .9 signifies the intervertebral disc beneath that vertebra. E.g. 5 = upper T5; 5.5 = lower T5; 5.9 = T5/6.

b Number with no decimal places signifies the rib or costal cartilage. Number ending in .5 signifies the intercostal space. E.g. 3 = third rib or costal cartilage; 3.5 = third intercostal space.
### Repeatability data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Azygos vein, vertebral level (cm)</th>
<th>Azygos vein, vertebral level (ICS)</th>
<th>Caudal apex (CC/ICS)</th>
<th>Caudal apex to midline (cm)</th>
<th>SVC formation (CC/ICS)</th>
<th>RCV formation</th>
<th>SVC/RA junction (CC/ICS)</th>
<th>SVC/RA junction</th>
<th>SVC/RA junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.9</td>
<td>8.9</td>
<td>1.6</td>
<td>1.3</td>
<td>1.5</td>
<td>Bilateral</td>
<td>3</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>2</td>
<td>5.5</td>
<td>7.2</td>
<td>1.8</td>
<td>2.5</td>
<td>2.5</td>
<td>Bilateral</td>
<td>4</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>3</td>
<td>5.9</td>
<td>7.3</td>
<td>2.5</td>
<td>3.5</td>
<td>3.5</td>
<td>Bilateral</td>
<td>5</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>4</td>
<td>7.6</td>
<td>8.6</td>
<td>3.6</td>
<td>4.5</td>
<td>4.5</td>
<td>Bilateral</td>
<td>6</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>5</td>
<td>7.6</td>
<td>8.6</td>
<td>4.6</td>
<td>5.5</td>
<td>5.5</td>
<td>Bilateral</td>
<td>7</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>6</td>
<td>5.6</td>
<td>6.6</td>
<td>6.6</td>
<td>7.6</td>
<td>7.6</td>
<td>Bilateral</td>
<td>8</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>7</td>
<td>5.6</td>
<td>6.6</td>
<td>7.6</td>
<td>8.6</td>
<td>8.6</td>
<td>Bilateral</td>
<td>9</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>8</td>
<td>5.6</td>
<td>6.6</td>
<td>8.6</td>
<td>9.6</td>
<td>9.6</td>
<td>Bilateral</td>
<td>10</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>9</td>
<td>5.6</td>
<td>6.6</td>
<td>9.6</td>
<td>10.6</td>
<td>10.6</td>
<td>Bilateral</td>
<td>11</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>10</td>
<td>5.6</td>
<td>6.6</td>
<td>11.6</td>
<td>12.6</td>
<td>12.6</td>
<td>Bilateral</td>
<td>13</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>11</td>
<td>5.6</td>
<td>6.6</td>
<td>12.6</td>
<td>13.6</td>
<td>13.6</td>
<td>Bilateral</td>
<td>14</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>12</td>
<td>5.6</td>
<td>6.6</td>
<td>13.6</td>
<td>14.6</td>
<td>14.6</td>
<td>Bilateral</td>
<td>15</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>13</td>
<td>5.6</td>
<td>6.6</td>
<td>14.6</td>
<td>15.6</td>
<td>15.6</td>
<td>Bilateral</td>
<td>16</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>14</td>
<td>5.6</td>
<td>6.6</td>
<td>15.6</td>
<td>16.6</td>
<td>16.6</td>
<td>Bilateral</td>
<td>17</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>15</td>
<td>5.6</td>
<td>6.6</td>
<td>16.6</td>
<td>17.6</td>
<td>17.6</td>
<td>Bilateral</td>
<td>18</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>16</td>
<td>5.6</td>
<td>6.6</td>
<td>17.6</td>
<td>18.6</td>
<td>18.6</td>
<td>Bilateral</td>
<td>19</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>17</td>
<td>5.6</td>
<td>6.6</td>
<td>18.6</td>
<td>19.6</td>
<td>19.6</td>
<td>Bilateral</td>
<td>20</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>18</td>
<td>5.6</td>
<td>6.6</td>
<td>19.6</td>
<td>20.6</td>
<td>20.6</td>
<td>Bilateral</td>
<td>21</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>19</td>
<td>5.6</td>
<td>6.6</td>
<td>20.6</td>
<td>21.6</td>
<td>21.6</td>
<td>Bilateral</td>
<td>22</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>20</td>
<td>5.6</td>
<td>6.6</td>
<td>21.6</td>
<td>22.6</td>
<td>22.6</td>
<td>Bilateral</td>
<td>23</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>21</td>
<td>5.6</td>
<td>6.6</td>
<td>22.6</td>
<td>23.6</td>
<td>23.6</td>
<td>Bilateral</td>
<td>24</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>22</td>
<td>5.6</td>
<td>6.6</td>
<td>23.6</td>
<td>24.6</td>
<td>24.6</td>
<td>Bilateral</td>
<td>25</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>23</td>
<td>5.6</td>
<td>6.6</td>
<td>24.6</td>
<td>25.6</td>
<td>25.6</td>
<td>Bilateral</td>
<td>26</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>24</td>
<td>5.6</td>
<td>6.6</td>
<td>25.6</td>
<td>26.6</td>
<td>26.6</td>
<td>Bilateral</td>
<td>27</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>25</td>
<td>5.6</td>
<td>6.6</td>
<td>26.6</td>
<td>27.6</td>
<td>27.6</td>
<td>Bilateral</td>
<td>28</td>
<td>Bilateral</td>
<td>Bilateral</td>
</tr>
</tbody>
</table>

\[ a \] Number with no decimal places signifies the upper half of the vertebral body. Number ending in .5 signifies the lower half of the vertebral body. Number ending in .9 signifies the intervertebral disc beneath that vertebra. E.g. 5 = upper T5; 5.5 = lower T5; 5.9 = T5/6.

\[ b \] Number with no decimal places signifies the rib or costal cartilage. Number ending in .5 signifies the intercostal space. E.g. 3 = third rib or costal cartilage; 3.5 = third intercostal space.
Reproducibility data

<table>
<thead>
<tr>
<th>Subject</th>
<th>RBCV formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
<th>SVC/RA formation (CC/ICS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.2</td>
<td>1.9</td>
<td>2.7</td>
<td>1.0</td>
<td>0.8</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>2.2</td>
<td>3.5</td>
<td>4.7</td>
<td>3.0</td>
<td>2.5</td>
<td>2.1</td>
<td>1.9</td>
<td>1.8</td>
<td>1.7</td>
<td>1.6</td>
<td>1.5</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>4.5</td>
<td>5.7</td>
<td>4.5</td>
<td>4.0</td>
<td>3.7</td>
<td>3.4</td>
<td>3.3</td>
<td>3.2</td>
<td>3.1</td>
<td>3.0</td>
<td>2.9</td>
<td>2.8</td>
</tr>
<tr>
<td>4</td>
<td>4.4</td>
<td>5.5</td>
<td>6.5</td>
<td>5.5</td>
<td>5.0</td>
<td>4.7</td>
<td>4.4</td>
<td>4.4</td>
<td>4.3</td>
<td>4.3</td>
<td>4.2</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>5</td>
<td>5.9</td>
<td>6.2</td>
<td>6.5</td>
<td>6.0</td>
<td>5.5</td>
<td>5.2</td>
<td>5.0</td>
<td>4.9</td>
<td>4.8</td>
<td>4.7</td>
<td>4.6</td>
<td>4.6</td>
<td>4.5</td>
</tr>
<tr>
<td>6</td>
<td>6.1</td>
<td>6.5</td>
<td>6.9</td>
<td>6.4</td>
<td>6.0</td>
<td>5.7</td>
<td>5.5</td>
<td>5.4</td>
<td>5.4</td>
<td>5.3</td>
<td>5.2</td>
<td>5.1</td>
<td>5.0</td>
</tr>
<tr>
<td>7</td>
<td>7.1</td>
<td>7.2</td>
<td>7.3</td>
<td>7.3</td>
<td>7.1</td>
<td>6.9</td>
<td>6.7</td>
<td>6.6</td>
<td>6.6</td>
<td>6.5</td>
<td>6.4</td>
<td>6.3</td>
<td>6.2</td>
</tr>
<tr>
<td>8</td>
<td>8.2</td>
<td>8.3</td>
<td>8.4</td>
<td>8.4</td>
<td>8.2</td>
<td>7.9</td>
<td>7.7</td>
<td>7.6</td>
<td>7.6</td>
<td>7.5</td>
<td>7.4</td>
<td>7.3</td>
<td>7.2</td>
</tr>
<tr>
<td>9</td>
<td>9.4</td>
<td>9.5</td>
<td>9.6</td>
<td>9.6</td>
<td>9.4</td>
<td>9.2</td>
<td>9.1</td>
<td>9.0</td>
<td>9.0</td>
<td>8.9</td>
<td>8.8</td>
<td>8.7</td>
<td>8.6</td>
</tr>
<tr>
<td>10</td>
<td>1.1</td>
<td>1.2</td>
<td>1.3</td>
<td>1.3</td>
<td>1.2</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>11</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
<td>2.3</td>
<td>2.2</td>
<td>2.2</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>12</td>
<td>3.1</td>
<td>3.2</td>
<td>3.3</td>
<td>3.3</td>
<td>3.2</td>
<td>3.2</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>13</td>
<td>4.1</td>
<td>4.2</td>
<td>4.3</td>
<td>4.3</td>
<td>4.2</td>
<td>4.2</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>14</td>
<td>5.1</td>
<td>5.2</td>
<td>5.3</td>
<td>5.3</td>
<td>5.2</td>
<td>5.2</td>
<td>5.1</td>
<td>5.1</td>
<td>5.1</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>15</td>
<td>6.1</td>
<td>6.2</td>
<td>6.3</td>
<td>6.3</td>
<td>6.2</td>
<td>6.2</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>16</td>
<td>7.1</td>
<td>7.2</td>
<td>7.3</td>
<td>7.3</td>
<td>7.2</td>
<td>7.2</td>
<td>7.1</td>
<td>7.1</td>
<td>7.1</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>17</td>
<td>8.1</td>
<td>8.2</td>
<td>8.3</td>
<td>8.3</td>
<td>8.2</td>
<td>8.2</td>
<td>8.1</td>
<td>8.1</td>
<td>8.1</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

a Number with no decimal places signifies the upper half of the vertebral body. Number ending in .5 signifies the lower half of the vertebral body. Number ending in .9 signifies the intervertebral disc beneath that vertebra. E.g. 5 = upper T5; 5.5 = lower T5; 5.9 = T5/6.
b Number with no decimal places signifies the rib or costal cartilage. Number ending in .5 signifies the intercostal space. E.g. 3 = third rib or costal cartilage; 3.5 = third intercostal space.
APPENDIX D

ULTRASONOGRAPHIC INVESTIGATION OF THE SUBCLAVIAN VEIN

ETHICAL APPROVAL MĀORI CONSULTATION PARTICIPANT INFORMATION CONSENT FORM PROFORMA
4 August 2010

Professor Mark Stringer
Department of Anatomy and Structural Biology
Otago School of Medical Sciences

Dear Mark,

Thank you for your letter of 3 August 2010 regarding the changes to the protocols of the project entitled: *An ultrasound study of veins in the upper chest (Ref 10/126)* together with the revised protocol, amended Information Sheet, Consent Form and Advertisement.

The Human Ethics Committee notes the changes as: scanning veins higher in the chest; modifying the exclusion criteria to exclude participants who have had previous chest surgery; subjects will also be scanned in the Vascular Laboratory of the Dunedin Public Hospital; and compensation in the form of a gift voucher will be increased from $20 to $25.

The Committee also notes that the investigators, methods and recruitment processes remain the same as the protocol already approved.

The Committee approves the changes and will file the amended documents with the original application.

Please note that the University of Otago Human Ethics Committee has no jurisdiction over the Dunedin Public Hospital facilities. It also does not require a Locality Assessment as part of its ethical approval process. The Committee trusts that the researchers will obtain the appropriate level permission for the scanning taking place at the Vascular Laboratory, Dunedin Public Hospital.

Thank you for keeping the Committee informed and all the best for the research.

Yours sincerely,

Gary Witte
Manager, Academic Committees
cc Associate Professor Oorschot, Department of Anatomy and Structural Biology
Title: An ultrasound study of veins in the upper chest.

The Ngāi Tahu Research Consultation Committee (The Committee) met on Tuesday, 22 June 2010 to discuss your research proposition.

By way of introduction, this response from the Committee is provided as part of the Memorandum of Understanding between Te Rūnanga o Ngāi Tahu and the University. In the statement of principles of the memorandum, it states "Ngāi Tahu acknowledges that the consultation process outlined in this policy provides no power of veto by Ngāi Tahu to research undertaken at the University of Otago". As such, this response is not "approval" or "mandate" for the research, rather it is a mandated response from a Ngāi Tahu appointed committee. This process is part of a number of requirements for researchers to undertake and does not cover other issues relating to ethics, including methodology; they are separate requirements with other committees, for example the Human Ethics Committee, etc.

Within the context of the Policy for Research Consultation with Māori, the Committee base consultation on that defined by Justice McGechan:

"Consultation does not mean negotiation or agreement. It means: setting out a proposal not fully decided upon; adequately informing a party about relevant information upon which the proposal is based; listening to what the others have to say with an open mind (in that there is room to be persuaded against the proposal); undertaking that task in a genuine and not cosmetic manner. Reaching a decision that may or may not alter the original proposal."

The Committee considers the research to be of importance to Māori health.

The Committee notes the researchers have identified that, "We will not be collecting ethnicity data as our sample size is too small to allow meaningful analysis of this information", however as this study involves human participants and it is the right of everyone to self identify who they are, the Committee strongly encourage that ethnicity data be collected as part of the research project. That is the questions on self-identified ethnicity and descent, these questions are contained in the 2006 census.

The Committee notes the researchers have identified that, "There are no data on whether complications from central venous catheters are more common among Māori but Māori may be more at risk of in-hospital adverse events…", but Māori present with cardiovascular
Ngāi Tahu Research Consultation Committee
Te Komiti Rakahau ki Kai Tahu

disease in higher proportion than non-Māori, and the Committee would refer you to Hauora: Māori Standards of Health IV (2000-2005) and Tautau Kahukura: Māori Health Chart Book 2010, 2nd Edition which is available from the Ministry of Health Website. These provide Māori specific information on a range of health issues.

The Committee suggests dissemination of the research findings to Māori health organisations regarding this study.

We wish you every success in your research and the Committee also requests a copy of the research findings.

This letter of suggestion, recommendation and advice is current for an 18 month period from Tuesday, 22 June 2010 to 22 December 2011.

The recommendations and suggestions above are provided on your proposal submitted through the consultation website process. These recommendations and suggestions do not necessarily relate to ethical issues with the research, including methodology. Other committees may also provide feedback in these areas.

Nāhaku noa, nā

Mark Brunton
Kaitakawaenga Rangahau Māori
Facilitator Research Māori
Research Division
Te Whare Wānanga o Otago
Ph: +64 3 479 8738
email: mark.brunton@otago.ac.nz
Web: www.otago.ac.nz

The Ngāi Tahu Research Consultation Committee has membership from:
Te Rūnanga o Ōtākou Incorporated
Kāti Huirapa Runanga ki Puketawahi
Te Rūnanga o Moeraki
Information Sheet

An ultrasound study of veins in the upper chest

You are invited to take part in a research study using ultrasound looking at a large vein next to each of your collarbones. Your participation is entirely voluntary. Please take as much time as you need to consider whether you wish to take part and to discuss this with family, whānau, and friends.

What is the purpose of this study?
Doctors often place thin tubes called catheters into large veins in the upper chest to give drugs and fluids into the circulation or to monitor heart function. It is important that they know exactly where these veins lie so as to minimise possible risks associated with inserting the catheters and ensure the greatest chance of successful placement. One vein that is often used is the subclavian vein. The collarbone (or "clavicle") is used as a guide to this vein, but only a few studies have looked at the exact relationships of the subclavian vein to this bone.

The purpose of this study is to help us understand precisely the relationship between the subclavian vein and the clavicle. This could help doctors insert catheters more easily, minimising the risks for patients. Ultrasound is a good way to do this because it is a painless and safe way of seeing what's under the skin. Ultrasound is used regularly to scan babies before birth and to diagnose internal problems.

Am I eligible to take part in this study?
You have been invited to take part in this study because you are over 18 years of age and have never had chest surgery or a central venous catheter. We are hoping to recruit up to 56 participants for this study.

What will be involved if I agree to take part?
You will first be asked to confirm that you have never had chest surgery or a central venous catheter before. We will then need to record your gender, age (in years and months) and measure your weight and height. After that, you will be asked to expose the top part of your chest. Your modesty will be preserved at all times. The scan will only be in the region of the collarbone. You will be asked to lie down on your back on a sloped examination couch with or without a soft pad between your shoulder blades. A clear hypoallergenic gel will be applied to the skin around your collarbone and a smooth plastic ultrasound probe will be gently pressed over the skin at this site. This will not cause any discomfort. We may have to mark a few points on your skin with a water soluble marker pen and make measurements between these points with a tape measure.

In the extremely unlikely event that an abnormality is found on your ultrasound scan, we will tell you of this finding and suggest that you inform your GP. Please note that this is NOT a scan of your heart.
• **Who will do the scans?** An experienced female ultrasound technician will do the scan in a private room, assisted by Sam Hale, a medical student.

• **Where?** The Clinical Anatomy area in the Department of Anatomy & Structural Biology, 2nd Floor Lindo Ferguson Building, 270 Great King Street, Dunedin or the Vascular Diagnostics Laboratory, 4th floor, Dunedin Public Hospital.

• **How long will it take?** Scans will take up to 30 minutes to complete. Your whole visit may last up to 45 minutes.

• **Will I be compensated?** If you are eligible for the study, and agree to take part, you will be offered a book token to the value of $25 after completing the scans.

**Can I withdraw from the study at any time?**
Yes, you can change your mind and withdraw without having to give a reason. There are no consequences if you decide to withdraw. After the scans have been completed you can no longer withdraw, so please consider this carefully.

**Are there any risks from taking part in this study? No**

**Are there any benefits from taking part in the study?**
The only real benefit is knowing that you are helping to map this vein which might help reduce the risk of complications when a venous catheter is inserted into a patient in the future.

**Will the information in the study be confidential?**
During and after the study, the information you provide will be kept confidential and stored securely at the University. Only the principal investigator, co-investigator, and ultrasound technician will have access to your data during and after the study. Your name will be removed to make the ultrasound pictures and other data anonymous. The researchers hope to have the results of this research published in a professional medical journal and presented at a conference but no material, which could personally identify you, will be used in any report. Anonymous data from the study will be stored for five years.

**Will I get to see the results of this study?**
There will be a delay of up to 6 months between doing the scans and analysing the results. You are welcome to contact the researchers for information about the results of the study when they become available.

**What are my rights?**
In the very unlikely event of a physical injury as a result of your participation in this study, you will be covered by the accident compensation legislation with its limitations. If you have any questions about ACC please feel free to ask the researchers for more information before you agree to take part.

If you have any queries or concerns about your rights as a participant in this study you may wish to contact a Health and Disability Services Consumer Advocate, telephone: (03) 479 0265 or freephone 0800 555 050 or free-fax 0800 2787 767 (0800 2 SUPPORT) or email advocacy@hdc.org.nz. If there is a specific Māori issue/concern please contact Linda Greenwell at 0800 377 766.

Thank you for considering taking part in this study. Please feel free to contact the researchers if you have any questions.

**For further information about this study please contact the researchers:**

- Sam Hale (sam.hale@anatomy.otago.ac.nz). Phone (03) 479-4030
- Professor Mark Stringer, Department of Anatomy & Structural Biology, Otago School of Medical Sciences, University of Otago, Dunedin. Phone (03) 479 5992

---

The University of Otago Human Ethics Committee has reviewed and approved this project.

Consent Form

An ultrasound study of veins in the upper chest

• I have read and understood the Information Sheet for volunteers taking part in this ultrasound study of veins in the upper chest.
• I have had the opportunity to ask questions and discuss the research study and I am satisfied with the answers to my questions.
• I have had the opportunity to use whānau support or a friend/family member to help me ask questions and understand the study.
• I have received enough information about this study and have had time to consider whether to take part.
• I understand that taking part in this study is entirely voluntary (my choice) and that I am free to withdraw from the study up to the point when the scans are completed. I do not have to give a reason and this would not affect my future healthcare.
• I understand that my participation in this study is confidential and that no material that could identify me personally will be used in any reports on this study. I understand that non-identifying data collected from me by the researchers will be stored on a secure computer at the University of Otago and may be published.
• I know whom to contact if I have any questions about the study.
• I am aware that I can contact the study investigators for a copy of the results of this study when they become available but that this may be up to six months from now.
• I understand that, in the unlikely event of a physical injury as a result of my participation in this study, I will be covered by the accident compensation legislation with its limitations.

I ........................................................................................................... (full name) hereby agree to take part in this study.
Signature: ............................................................................... Date: ............................................................................

The University of Otago Human Ethics Committee has reviewed and approved this project. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph: 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Researchers: Sam Hale (sam.hale@anatomy.otago.ac.nz) and Professor Mark Stringer, Department of Anatomy & Structural Biology, Otago School of Medical Sciences, University of Otago, Dunedin.
Phone: (03) 479 4030

An ultrasound study of veins in the upper chest

Contact details

1. Mr ☐ Ms ☐ Dr ☐ Other ☐ ........................
   Surname ........................................ Given names ............................................

2. 2a. Phone number ........................................................................................................
2b. Email address ...........................................................................................................

(This page will be separated from the proforma and destroyed after data entry is complete to prevent participants being identified during data capture and analysis.)
Proforma

An ultrasound study of veins in the upper chest

Subject Details

3. Age (years/months) .......... Gender ........

4. Weight (kg) ............... BMI ............
   Height (m) ............... 

5. Have you had chest surgery? Yes □ No □

6. Have you had a catheter in the veins of your upper chest or neck? Yes □ No □

7. Has a doctor ever told you that you have an anatomical abnormality in your upper chest or neck? Yes □ No □
### Ultrasonographic measurements

<table>
<thead>
<tr>
<th>Ultrasound</th>
<th>LEFT</th>
<th>RIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clavicle - vein (mm)</td>
<td>FLAT</td>
<td>BAG</td>
</tr>
<tr>
<td>Notch - clavicle (cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter (closest to clavicle)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of clavicle (cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subclavian valves (distance from UV/SCV jct) (mm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An ultrasound study of veins in the upper chest, Assessment Form, Version 2 (6/08/10)
APPENDIX E

ULTRASONOGRAPHIC INVESTIGATION OF THE SUBCLAVIAN VEIN

RAW DATA
<table>
<thead>
<tr>
<th>Age</th>
<th>Weight (kg)</th>
<th>Gender</th>
<th>Distance (cm)</th>
<th>Angle (º)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.591</td>
<td>55.2</td>
<td>M</td>
<td>16.7</td>
<td>39</td>
</tr>
<tr>
<td>1.758</td>
<td>55.7</td>
<td>M</td>
<td>15.5</td>
<td>64</td>
</tr>
<tr>
<td>1.744</td>
<td>84.4</td>
<td>M</td>
<td>16.6</td>
<td>40</td>
</tr>
<tr>
<td>1.817</td>
<td>99.6</td>
<td>M</td>
<td>14.8</td>
<td>39</td>
</tr>
<tr>
<td>1.617</td>
<td>56.9</td>
<td>M</td>
<td>15.4</td>
<td>73</td>
</tr>
<tr>
<td>1.823</td>
<td>73.9</td>
<td>M</td>
<td>18.5</td>
<td>61</td>
</tr>
<tr>
<td>1.688</td>
<td>65.1</td>
<td>M</td>
<td>13.5</td>
<td>16</td>
</tr>
<tr>
<td>1.744</td>
<td>67.4</td>
<td>M</td>
<td>15.7</td>
<td>48</td>
</tr>
<tr>
<td>1.765</td>
<td>65.5</td>
<td>M</td>
<td>14.7</td>
<td>66</td>
</tr>
<tr>
<td>1.738</td>
<td>81.5</td>
<td>M</td>
<td>14.5</td>
<td>32</td>
</tr>
</tbody>
</table>

Original measurements
Repeatability data

<table>
<thead>
<tr>
<th>Subject</th>
<th>L clavicle length (cm)</th>
<th>R clavicle length (cm)</th>
<th>Mean L vein-clavicle (mm)</th>
<th>Mean R vein-clavicle (mm)</th>
<th>Mean L vein-clavicle with bag (mm)</th>
<th>Mean R vein-clavicle with bag (mm)</th>
<th>Mean L diameter (mm)</th>
<th>Mean R diameter (mm)</th>
<th>Mean L diameter with bag (mm)</th>
<th>Mean R diameter with bag (mm)</th>
<th>L distance to notch (cm)</th>
<th>R distance to notch (cm)</th>
<th>L distance to notch with bag (cm)</th>
<th>R distance to notch with bag (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>15.3</td>
<td>14.4</td>
<td>11.0</td>
<td>11.0</td>
<td>9.3</td>
<td>11.4</td>
<td>14.8</td>
<td>11.1</td>
<td>13.0</td>
<td>6.7</td>
<td>7</td>
<td>6.7</td>
<td>7.4</td>
<td>6.6</td>
</tr>
<tr>
<td>6</td>
<td>14.4</td>
<td>13.8</td>
<td>5.9</td>
<td>5.4</td>
<td>7.3</td>
<td>7.5</td>
<td>8.4</td>
<td>8.6</td>
<td>7.3</td>
<td>6.6</td>
<td>6</td>
<td>5.3</td>
<td>7.2</td>
<td>6.2</td>
</tr>
<tr>
<td>11</td>
<td>14</td>
<td>15.8</td>
<td>4.3</td>
<td>3.6</td>
<td>5.0</td>
<td>7.8</td>
<td>12.9</td>
<td>6.7</td>
<td>5.4</td>
<td>4.5</td>
<td>6</td>
<td>5.7</td>
<td>6.2</td>
<td>5.7</td>
</tr>
<tr>
<td>12</td>
<td>15.7</td>
<td>15.3</td>
<td>9.1</td>
<td>8.0</td>
<td>4.8</td>
<td>8.5</td>
<td>6.5</td>
<td>8.6</td>
<td>6.0</td>
<td>7.9</td>
<td>7.1</td>
<td>7.5</td>
<td>6.5</td>
<td>5.7</td>
</tr>
<tr>
<td>17</td>
<td>14.6</td>
<td>13.4</td>
<td>11.6</td>
<td>10.0</td>
<td>9.2</td>
<td>8.4</td>
<td>11.2</td>
<td>9.9</td>
<td>9.4</td>
<td>6.6</td>
<td>7.2</td>
<td>6.5</td>
<td>7.8</td>
<td>7.0</td>
</tr>
<tr>
<td>22</td>
<td>15.7</td>
<td>15.1</td>
<td>12.2</td>
<td>14.1</td>
<td>10.7</td>
<td>13.5</td>
<td>11.7</td>
<td>11.6</td>
<td>10.6</td>
<td>7.8</td>
<td>7.7</td>
<td>6.8</td>
<td>7.5</td>
<td>7.8</td>
</tr>
<tr>
<td>23</td>
<td>15.6</td>
<td>16.2</td>
<td>10.6</td>
<td>9.9</td>
<td>10.2</td>
<td>9.4</td>
<td>8.6</td>
<td>12.2</td>
<td>8.4</td>
<td>10.8</td>
<td>8.2</td>
<td>8</td>
<td>7.5</td>
<td>7.9</td>
</tr>
<tr>
<td>47</td>
<td>14.8</td>
<td>14.8</td>
<td>15.7</td>
<td>10.1</td>
<td>10.7</td>
<td>10.6</td>
<td>10.6</td>
<td>13.2</td>
<td>10.8</td>
<td>7.7</td>
<td>7.9</td>
<td>8.2</td>
<td>7.9</td>
<td>6.8</td>
</tr>
</tbody>
</table>
Measurements stratified by age, gender and BMI without passive shoulder retraction

<table>
<thead>
<tr>
<th>Age Group</th>
<th>SCV to clavicle (mm)</th>
<th>Mean with shoulder retraction ± SD (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-29.9 years (n=21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>7.3 ± 2.1 (4.6-12.8)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>7.2 ± 2.0 (4.2-11.3)*</td>
<td></td>
</tr>
<tr>
<td>30-49.9 years (n=19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>8.8 ± 2.4 (5.3-15.0)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>9.2 ± 2.2 (6.1-13.6)*</td>
<td></td>
</tr>
<tr>
<td>50+ years (n=10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>8.6 ± 2.4 (5.6-12.1)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>8.5 ± 2.8 (4.8-12.6)*</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Venous diameter (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (n=25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>9.9 ± 2.5 (3.9 ± 14.0)*</td>
<td>10.8 ± 2.7 (6.0-16.9)*</td>
</tr>
<tr>
<td>Right</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (n=25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>8.1 ± 2.0 (2.7-11.5)*</td>
<td>8.5 ± 1.9 (4.3-12.0)*</td>
</tr>
<tr>
<td>Right</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BMI</th>
<th>Venous diameter (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI &lt; 25 (n=30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>8.3 ± 2.4 (2.7-13.7)*</td>
<td>9.1 ± 2.8 (4.3-16.9)</td>
</tr>
<tr>
<td>Right</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI &gt; 25 (n=20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>10.1 ± 1.8 (6.8-14)*</td>
<td>10.6 ± 1.9 (6.7-14.7)</td>
</tr>
<tr>
<td>Right</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant association (p<0.05).  a n=24
APPENDIX F

ULTRASONOGRAPHIC INVESTIGATION OF THE SUBCLAVIAN VEIN

PRESENTATION ABSTRACT
ANZACA 2010, HOBART, TASMANIA, AUSTRALIA
DEFINING THE SURFACE ANATOMY OF THE SUBCLAVIAN VEIN BY ULTRASOUND

HALE SJM¹, GB HILL², MD STRINGER¹

¹Department of Anatomy & Structural Biology, Otago School of Medical Sciences
²Department of Surgery, Dunedin School of Medicine
University of Otago, Dunedin, New Zealand

Purpose: In an emergency, central venous access is often obtained via infraclavicular subclavian vein catheterisation without imaging guidance. Clinicians need to be aware of the surface anatomy of the vein to optimise successful puncture and minimise potentially serious complications. Only a few studies have examined the surface anatomy of the vein and how this is affected by body posture. This study investigates these aspects in healthy participants using ultrasound.

Methods: The subclavian vein was identified bilaterally using a 13-5 MHz linear probe in 21 healthy volunteers (9 female, mean age 27.8 years, BMI 16.5-34.1), with and without a litre bag of saline between the scapulae. The following were recorded in both positions with 10 degrees of head-down tilt: the closest distance between the vein and superior border of the clavicle, the distance from this point to the mid-jugular notch, and the venous diameter.

Results: The subclavian vein was closest to the superior border of the clavicle at a mean of 7cm from the jugular notch on the left and 7.2cm on the right; this was within 1cm of the mid-clavicular line in 60% of participants. With shoulder retraction, the vein moved slightly nearer the jugular notch (mean distance 6.8cm bilaterally, p< 0.02) but its distance from the clavicle and diameter were minimally affected.

Conclusion: In most healthy subjects, the subclavian vein is closest to the clavicle behind the mid-clavicular region, irrespective of shoulder retraction. This information may facilitate percutaneous subclavian vein puncture.
APPENDIX G

ULTRASONOGRAPHIC INVESTIGATION OF THE SVC/RA JUNCTION

ETHICAL APPROVAL
MĀORI CONSULTATION PARTICIPANT INFORMATION CONSENT FORM ADVERTISEMENT
Professor M Stringer  
Department of Anatomy and Structural Biology  
Otago School of Medical Sciences

18 June 2010

Dear Professor Stringer,

I am writing to let you know that, at its recent meeting, the Ethics Committee considered your proposal entitled “An ultrasound study of veins in the upper chest”.

As a result of that consideration, the current status of your proposal is:- Approved

For your future reference, the Ethics Committee’s reference code for this project is:- 10/126.

Approval is for up to three years. If this project has not been completed within three years from the date of this letter, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Mr Gary Witte  
Manager, Academic Committees  
Tel: 479.8565  
Email: gary.witte@otago.ac.nz

c.c. Assoc. Prof. D E Oorschot  Head  Department of Anatomy and Structural Biology
NGĀI TAHU RESEARCH CONSULTATION COMMITTEE
TE KOMITI RAKAHAU KI KAI TAHU

22/06/2010 - 36
Tuesday, 22 June 2010

Professor Stringer
Anatomy and Structural Biology
Dunedin

Tīnā kee Professor Stringer

Title: An ultrasound study of veins in the upper chest.

The Ngāi Tahu Research Consultation Committee (The Committee) met on Tuesday, 22 June 2010 to discuss your research proposition.

By way of introduction, this response from the Committee is provided as part of the Memorandum of Understanding between Te Rūnanga o Ngāi Tahu and the University. In the statement of principles of the memorandum, it states "Ngāi Tahu acknowledges that the consultation process outlined in this policy provides no power of veto by Ngāi Tahu to research undertaken at the University of Otago". As such, this response is not "approval" or "mandate" for the research, rather it is a mandated response from a Ngāi Tahu appointed committee. This process is part of a number of requirements for researchers to undertake and does not cover other issues relating to ethics, including methodology; they are separate requirements with other committees, for example the Human Ethics Committee, etc.

Within the context of the Policy for Research Consultation with Māori, the Committee base consultation on that defined by Justice McGechan:

"Consultation does not mean negotiation or agreement. It means: setting out a proposal not fully decided upon; adequately informing a party about relevant information upon which the proposal is based; listening to what the others have to say with an open mind (in that there is room to be persuaded against the proposal); undertaking that task in a genuine and not cosmetic manner. Reaching a decision that may or may not alter the original proposal."

The Committee considers the research to be of importance to Māori health.

The Committee notes the researchers have identified that, “We will not be collecting ethnicity data as our sample size is too small to allow meaningful analysis of this information”; however, as this study involves human participants and it is the right of everyone to self identify who they are, the Committee strongly encourage that ethnicity data be collected as part of the research project. That is the questions on self-identified ethnicity and descent, these questions are contained in the 2006 census.

The Committee notes the researchers have identified that, “There are no data on whether complications from central venous catheters are more common among Māori but Māori may be more at risk of in-hospital adverse events…”, but Māori present with cardiovascular

The Ngāi Tahu Research Consultation Committee has membership from:
Te Rūnanga o Ōtākou Incorporated
Kāti Huirapa Rūnanga ki Puketeraki
Te Rūnanga o Moeroa
Ngāi Tahu Research Consultation Committee
Te Komiti Rakahau ki Kai Tahu

disease in higher proportion than non-Māori, and the Committee would refer you to Hinuera: Māori Standards of Health IV (2000-2005) and Tautu Kahukura: Māori Health Chart Book 2010, 2nd Edition which is available from the Ministry of Health Website. These provide Māori specific information on a range of health issues.

The Committee suggests dissemination of the research findings to Māori health organisations regarding this study.

We wish you every success in your research and the Committee also requests a copy of the research findings.

This letter of suggestion, recommendation and advice is current for an 18 month period from Tuesday, 22 June 2010 to 22 December 2011.

The recommendations and suggestions above are provided on your proposal submitted through the consultation website process. These recommendations and suggestions do not necessarily relate to ethical issues with the research, including methodology. Other committees may also provide feedback in these areas.

Nāhaku noa, nā

[Signature]

Mark Brunton
Kaitakawaenga Rangahau Māori
Facilitator Research Māori
Research Division
Te Whare Wānanga o Otago
Ph: +64 3 479 8738
e-mail: mark.brunton@otago.ac.nz
Web: www.otago.ac.nz

The Ngāi Tahu Research Consultation Committee has membership from:
Te Rūnanga o Ōtākou Incorporated
Kāti Huirapa Rātaka ki Paketike
Te Rūnanga o Moeraki

144
Information Sheet

An ultrasound study of veins in the upper chest

You are invited to take part in a research study using ultrasound to see where a large vein in the upper chest enters the heart. Your participation is entirely voluntary. Please take as much time as you need to consider whether you wish to take part and to discuss this with family, whānau, and friends.

What is the purpose of this study?
Doctors often place thin tubes called catheters into large veins in the upper chest to give drugs and fluids into the circulation or to monitor heart function. To reduce the risk of any harmful side effects such as blood clots, the end of the tube must be positioned correctly and so the doctor must know whereabouts the main vein (the superior vena cava) enters the heart. It is thought that this is behind the right third rib in most people but this information is based on only a few studies.

The purpose of this study is to help us understand precisely where the superior vena cava enters the heart. This could help doctors position the end of the venous catheter more accurately and so minimise the risks for patients. Ultrasound is a good way to do this because it is a painless and safe way of seeing what's under the skin. Ultrasound is used regularly to scan babies before birth and to diagnose internal problems.

Am I eligible to take part in this study?
You have been invited to take part in this study because you are over 18 years of age and have never had any problems with your heart or major problems with your lungs, or spine. We are hoping to recruit up to 50 participants for this study.

What will be involved if I agree to take part?
You will first be asked to confirm that you have never had any problems with your heart, lungs or spine. We will then need to record your gender, age (in years and months) and measure your weight and height.

After that, you will be asked to expose the upper half of your chest. Your modesty will be preserved at all times and, if you are a woman, you should leave your bra on. The scan does not go below the neck line of a typical v-necked t-shirt. You will be asked to lie down on your back on a flat examination couch. A clear hypoallergenic gel will be applied to the skin of your upper chest and a smooth plastic ultrasound probe will be gently passed over the skin at this site. This will not cause any discomfort. We may have to mark a few points on your skin with a water soluble marker pen.

In the extremely unlikely event that an abnormality is found on your ultrasound scan, we will tell you of this finding and suggest that you inform your GP. Please note that this is not a scan of your heart.

• **Who will do the scans?** An experienced female ultrasound technician will do the scan in a private room, assisted by Sam Hale, a medical student.

• **Where?** The Clinical Anatomy area in the Department of Anatomy & Structural Biology, 2nd Floor Lindo Ferguson Building, 276 Great King Street, Dunedin

• **How long will it take?** Scans will take up to 20 minutes to complete. Your whole visit may last up to 30 minutes.

• **Will I be compensated?** If you are eligible for the study, and agree to take part, you will be offered a book token to the value of $20 after completing the scans.

**Can I withdraw from the study at any time?**

Yes, you can change your mind and withdraw without having to give a reason. There are no consequences if you decide to withdraw. After the scans have been completed you can no longer withdraw, so please consider this carefully.

**Are there any risks from taking part in this study? No**

**Are there any benefits from taking part in the study?**

The only real benefit is knowing that you are helping to map this vein which might help reduce the risk of complications when a venous catheter is inserted into a patient in the future.

**Will the information in the study be confidential?**

During and after the study, the information you provide will be kept confidential and stored securely at the University. Only the principal investigator, co-investigator, and ultrasound technician will have access to your data during and after the study. Your name will be removed to make the ultrasound pictures and other data anonymous. The researchers hope to have the results of this research published in a professional medical journal and presented at a conference but no material, which could personally identify you, will be used in any report. Anonymous data from the study will be stored for five years.

**Will I get to see the results of this study?**

There will be a delay of up to 6 months between doing the scans and analysing the results. You are welcome to contact the researchers for information about the results of the study when they become available.

**What are my rights?**

In the very unlikely event of a physical injury as a result of your participation in this study, you will be covered by the accident compensation legislation with its limitations. If you have any questions about ACC please feel free to ask the researchers for more information before you agree to take part.

If you have any queries or concerns about your rights as a participant in this study you may wish to contact a Health and Disability Services Consumer Advocate, telephone (03) 479 0265 or freephone 0800 555 050 or free-fax 0800 2787 7678 (0800 2 SUPPORT) or email advocacy@hdsc.org.nz. If there is a specific Māori issue/concern please contact Linda Grennell at 0800 377 766.

Thank you for considering taking part in this study. Please feel free to contact the researchers if you have any questions.

**For further information about this study please contact the researchers:**

- Sam Hale (sam.hale@anatomy.otago.ac.nz). Phone (03) 479 4030
- Professor Mark Stringer, Department of Anatomy & Structural Biology, Otago School of Medical Sciences, University of Otago, Dunedin. Phone (03) 479 5992

---

The University of Otago Human Ethics Committee has reviewed and approved this project.

Consent Form

An ultrasound study of veins in the upper chest

- I have read and understood the Information Sheet for volunteers taking part in this ultrasound study of the veins of the upper chest.
- I have had the opportunity to ask questions and discuss the research study and I am satisfied with the answers to my questions.
- I have had the opportunity to use whānau support or a friend/family member to help me ask questions and understand the study.
- I have received enough information about this study and have had time to consider whether to take part.
- I understand that taking part in this study is entirely voluntary (my choice) and that I am free to withdraw from the study up to the point when the scans are completed. I do not have to give a reason and this would not affect my future healthcare.
- I understand that my participation in this study is confidential and that no material that could identify me personally will be used in any reports on this study. I understand that non-identifying data collected from me by the researchers will be stored on a secure computer at the University of Otago and may be published.
- I know whom to contact if I have any questions about the study.
- I am aware that I can contact the study investigators for a copy of the results of this study when they become available but that this may be up to six months from now.
- I understand that, in the unlikely event of a physical injury as a result of my participation in this study, I will be covered by the accident compensation legislation with its limitations.

[Consent Form Signature]

I .................................................................................................................. (full name) hereby agree to take part in this study.

Signature: .......................................................................................... Date: ..............................................................

The University of Otago Human Ethics Committee has reviewed and approved this project. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Researchers: Sam Hale (sam.hale@anatomy.otago.ac.nz) and Professor Mark Stringer, Department of Anatomy & Structural Biology, Otago School of Medical Sciences, University of Otago, Dunedin.
Phone: (03) 479 4030

Are you aged 18 years or more?
AND
You don’t have any problems with your heart, lungs or spine?

If so, you may be able to take part in an ultrasound study to identify where a major vein enters your heart

The study involves you having an ultrasound scan of your upper chest. This should cause no discomfort or embarrassment.

This proposal has been reviewed and approved by the Department of Anatomy & Structural Biology, University of Otago

If you are interested or would like further information please contact
Sam Hale at sam.hale@anatomy.otago.ac.nz

| Ultrasound imaging study of a major vein in the chest | CONTACT 479 4030 | sam.hale@anatomy.otago.ac.nz |
| Ultrasound imaging study of a major vein in the chest | CONTACT 479 4030 | sam.hale@anatomy.otago.ac.nz |
| Ultrasound imaging study of a major vein in the chest | CONTACT 479 4030 | sam.hale@anatomy.otago.ac.nz |