THE RELATIONSHIP BETWEEN THE INTERCOSTAL DISTANCE, PATIENT HEIGHT AND OUTCOME IN MICROSURGICAL BREAST RECONSTRUCTION USING THE SECOND INTERSPACE RIB-SPARING INTERNAL MAMMARY VESSEL EXPOSURE

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Purpose of the study: Rib-sparing internal mammary vessel (IMV) exposure in breast reconstruction is becoming common, with a smaller space in which to perform the microanastomoses. The objectives were to determine whether patient height could be used as a proxy measurement for intercostal distance (ICD), assess whether the complication rate or the flap ischemia time are affected in such surgery, and provide anatomical data about ICDs. *Methods:* Data were collected from 95 consecutive patients (109 breasts) undergoing free flap breast reconstruction using rib-sparing vessel exposure over a 3-year period by one surgeon. Pearson's product moment correlation coefficient was used to assess the relation between height and ICD, body mass index (BMI), operative times, and flap outcomes. *Results:* There was no correlation between patient height and ICD ($r = 0.087$), age, BMI, recipient vessel preparation time, and flap ischemia time. *Conclusion:* Being able to predict patients with a small ICD in whom microsurgery may be more challenging can influence surgical planning. The anatomy of the intercostal spaces is variable and was not predictable in relation to height, BMI, or age. Height was not a reliable proxy for ICD and where there is a concern about the available ICD it is suggested that it is measured directly through preoperative imaging. This study found no increase in the complication rate and flap ischemia time using the rib-sparing IMV exposure technique.

Autologous free flap breast reconstruction is considered the optimum technique for breast reconstruction. The transverse rectus abdominis musculocutaneous (TRAM) flap was first described in 1982 by Hartrampf et al.[1] and, in its various forms, has been established as the "gold standard" for autologous breast reconstruction.[2] Donor site morbidity varies depending on the amount of rectus muscle and fascia sacrificed; ranging from the "conventional" pedicled TRAM, through free muscle-sparing TRAMs[3] to the deep inferior epigastric perforator (DIEP) and superficial inferior epigastric artery (SIEA) free flaps.[4,5]

The internal mammary vessels (IMVs) have gained popularity as the recipient vessels for microsurgical anastomoses during breast reconstruction.[6,7] The rib-sacrificing technique of IMV exposure continues to be more widely used as it provides the microsurgeon with a significantly larger space in which to conduct the anastomoses. However, rib-sparing IMV exposure has been described as an alternative to rib-sacrificing methods.[8,9] Preserving the continuity of the rib conserves the normal contour of the chest wall and decreases both postoperative analgesia requirements and long-term tenderness, leading to a shortened recovery time and overall improved patient experience.[10] Therefore, we strongly advocate the rib-sparing technique for IMV exposure, although there is a learning curve in becoming proficient at performing microsurgery in a significantly reduced space.

Although there are detailed anatomical studies of the characteristics of the IMVs and their relationship to the sternum at this site, these do not include information about the intercostal space distance itself.[11–14] When using the rib-sparing technique, not only the characteristics of the IMVs but also the characteristics of the intercostal space are pertinent to the surgeon. A larger or smaller intercostal space may significantly contribute to the technical ease and potentially to the success or otherwise of the free tissue transfer. Therefore, we believe that being able to predict the intercostal distances (ICDs) preoperatively would be useful, particularly for less-experienced microsurgeons wishing to start undertaking total rib-sparing preparation of the internal mammary recipients. This study was in part stimulated by an observation by Han et al.[15] that Asian women had smaller ICDs than Caucasian women. Although we would intuit

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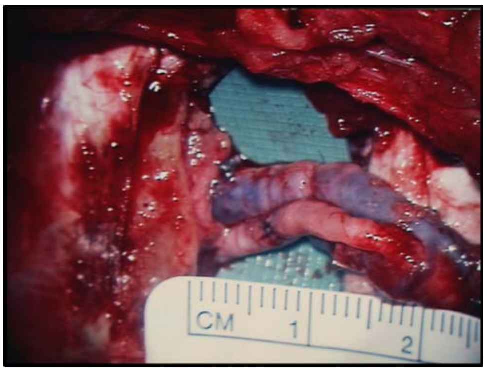


Figure 1. Measurement of ICD between the second and third costal cartilages. In this patient it measured 13 mm and the completed microsurgical anastomoses are illustrated. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

that this was correct, as Asian women in general tend to be of more petite build than Caucasians, a literature search failed to find any data to support this observation. We hypothesized that intercostal space distance was proportional to patient height and, therefore, height could be used as a proxy for the ICD. In addition, two secondary objectives were to: (a) assess whether the complication rate or the flap ischemia time are affected in such surgery and (b) provide anatomical data about ICDs pertinent to IMV exposure.

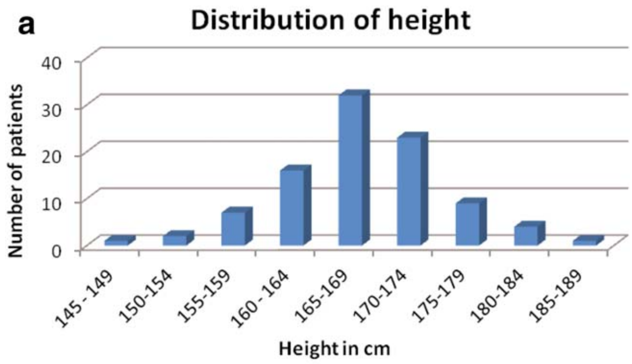
METHODS

Data were collected prospectively from all women undergoing free flap breast reconstruction by the senior author (C.M.M.) using the total rib-sparing method of IMV exposure in the second intercostal space over a 3-year period (July 1, 2008 to June 30, 2011). We recorded patient age, height, weight, body mass index (BMI), flap type, flap ischemia time, vessel exposure time, and laterality. Flap ischemia time was defined as the length of time that the flap was deprived of a blood supply, from the moment the deep inferior epigastric artery was divided in the abdomen to the time it was anastomosed to the IMVs. Complications included were those encountered during the patient's initial hospital stay and directly related to the free flap, for example, complications in performing the anastomoses and postoperative flap compromise, rather than general complications such as urinary retention or chest infection, and excluding longer term complications such as fat necrosis or abdominal seroma. The ICD was estimated as the mean of three measurements of the distance between the second and third costal cartilage overlying the internal mammary artery using a standard surgical ruler (Fig. 1). The measurements were undertaken by the surgeon exposing the vessels and confirmed intraoperatively by the senior author using microscope magnification. The senior author was always the scrubbed supervising surgeon, although grade of primary surgeon (dissecting out the IMVs or performing the microanastomoses) varied affecting vessel exposure and flap ischemia times. The measurements were taken at the level of the artery rather than the vein as it has a straighter course and is not usually bifurcated in the second space.[16,17] The Pearsons product moment correlation test was applied to each continuous variable: age, BMI, height, ICD, and flap ischemia time. A value of $P < 0.05$ was considered statistically significant for all tests. The software Excel 2010 (Microsoft Corporation) was used for statistical calculations.

RESULTS

There were a total of 95 women/109 breasts in the study, with bilateral procedures in 14 patients. Forty-nine procedures (45%) were right-sided and 60 procedures (55%) were left-sided reconstructions. Seventy-eight (72%) procedures were immediate breast reconstructions and 31 (28%) procedures were delayed. The types of free flap reconstruction were: DIEP flaps (89 cases), SIEA perforator flaps (12 cases), inferior gluteal artery perforator flaps (two cases), and muscle-sparing transverse rectus abdominis myocutaneous flaps (six cases).

The mean patient age was 51 ± 10.03 years (ranging 28–68 years). The mean height was 165 ± 16.45 cm (ranging 145–185 cm). The mean ICD was 20.3 ± 3.31 mm (ranging 13–29 mm). All values were normally distributed (Figs. 2a and 2b). The tallest woman (185 cm) in our group had an ICD of 25 mm: the shortest woman (145 cm) had an ICD of 20 mm. The widest ICD in our group of women was 29 mm (in a woman of 160 cm) and the narrowest ICD was 13 mm (in a woman of 154 cm). The mean time for vessel exposure was 56 ± 26.18 min with a range of 17–131 min. The mean flap ischemia time was 98 ± 20.07 min with a range of 38–169 min. The venous anastomotic coupler was used in 31 cases, all in the latter part of the study. Two on-table anastomotic complications were documented; in the first, the venous anastomosis was initially performed with the coupler, but flow was observed to be sluggish and the anastomosis was taken down and successfully hand sewn using 9/0 monofilament nylon (continuous technique). In the second, the arterial anastomosis was redone three times (in the same space) until satisfactory flow observed. The flap was successful. In 91 flaps (83%), one venous anastomosis was performed, whereas in 18 flaps (17%), two venous anastomoses were performed. Postoperatively one patient who had had a delayed SIEA flap on the left side underwent reexploration of the flap at 24 hours as the flap was observed to be intermittently



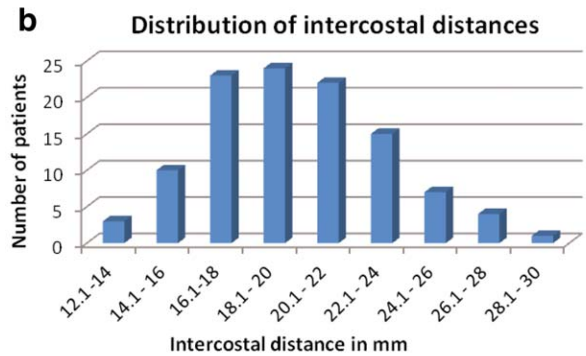


Figure 2. (a) Distribution of height in patients undergoing total rib preservation exposure of the internal mammary recipient vessels. The average height was 165 cm. (b) Distribution of intercostal space distance in patients undergoing total rib preservation exposure of the internal mammary recipient vessels. The average ICD was 20.3 mm. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

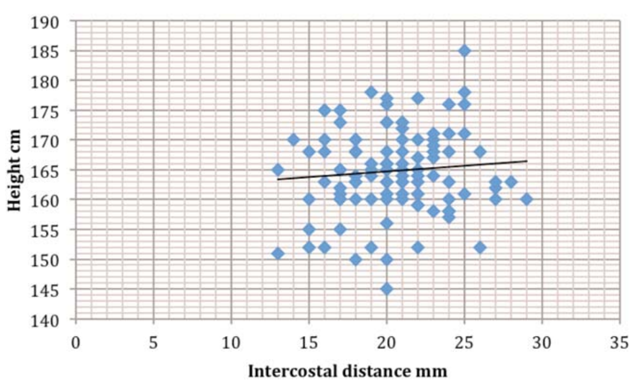


Figure 3. Plot of ICD versus height. Each blue rhomboid in the scatter diagram represents an individual patient, with the rhomboids widely scattered throughout the graph showing lack of correlation between the ICD and height (r = 0.087). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

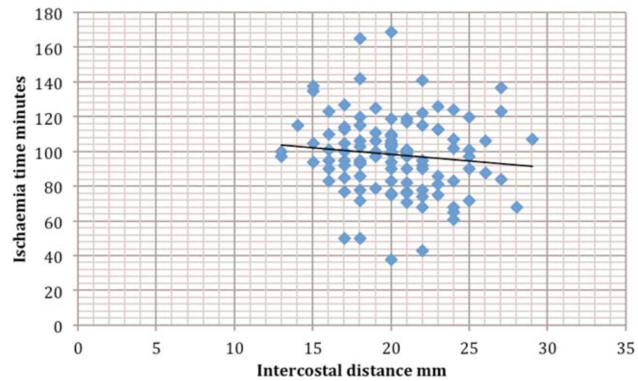


Figure 4. Plot of ICD versus flap ischemia time. Each blue rhomboid in the scatter diagram represents an individual patient, with the rhomboids widely scattered throughout the graph showing lack of correlation between the ICD and flap ischemia time (r = −0.114). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

dusky in color. Operative findings showed an insignificant external blood clot around the venous anastomosis which could have been potentially limiting outflow. The anastomosis was patent and did not require revision. The reexploration rate in this consecutive series was therefore <1%. There were no flap losses in the entire series.

Statistical analyses was performed using the Pearson product moment correlation test which is a measure of the linear correlation between two variables, where 1 is total positive correlation, 0 is no correlation, and −1 is total negative correlation. The results showed a very weak positive correlation between height and ICD ($r = 0.087$), which was demonstrated by the wide scattering of patients in Figure 3. The finding was not statistically significant ($P = 0.37$) thus showing no significant correlation between height and ICD. Similarly, using the Pearson product moment correlation test there was no significant correlation between ICD and BMI ($r = -0.174$, $P = 0.07$), ICD and age ($r = 0.079$, $P = 0.41$) or ICD and flap ischemia time ($r = -0.114$, $P = 0.24$, Fig. 4). Results remained the same when stratified for laterality, and for delayed versus immediate procedures. The flap ischemia data (Fig. 4) showed a small negative correlation between the flap ischemia time and the ICD ($r = -0.114$, $P = 0.24$) but this did not reach statistical significance.

DISCUSSION

We proposed using height as a proxy for ICD based on the assumption that skeletal relationships are proportional, as forensic anthropology describes formulae for estimating height from anthropometric data such as long bone length (femur/tibia/humerus).[18–20] However, the lack of correlation in our group did not bear out the assumption that taller women would tend to have wider intercostal space distances and shorter women narrower intercostal space distances. Mature skeletal height is the result of many interacting factors including genetic, nutritional, and endocrine factors, and after the age of 30 there is a cumulative decline of height, with 1 cm lost every 10 years until the age of 70, when the decline accelerates. The onset and rate of height loss is affected by factors such as weight, exercise, and osteoporosis; that is, if there was a relationship between height and ICD, this may be obscured by other factors that are differentially influential, particularly after the age of 30.[21]It may be that other parameters are better proxies for ICD, such as bone density, or that ethnicity, for example, may relate to ICD independently of height: we did not investigate these relationships (our data had limited ethnic spread and only a minority of women had undergone bone scans).

The characteristics of the IMVs have been extensively described by both plastic and cardiothoracic surgeons, as have the spatial relations of the vessels to the sternum.[22] However, until a recent study by Tuinder et al.[23] who used magnetic resonance imaging (MRI) to delineate the characteristics of the intercostal spaces and IMVs, the intercostal space characteristics had been neglected. The DIEP flap in particular has a steep learning curve: additional information gained from imaging the flap/donor vasculature has demonstrated improvements in complication rates and operative time.[24–27] Information about the characteristics of the recipient site may contribute further improvements and be of especial relevance to a surgeon considering performing total rib-sparing vessel exposure. Computed tomography (CT) angiography for preoperative planning of the donor site was first described by Masia et al.[28] in 2006 and has gained popularity amongst some reconstructive surgeons. The recipient site is not usually imaged preoperatively, although this may change as it becomes more common to use internal mammary perforators to anastomose the flap vessels. We chose to examine ICDs in relation to height, age, and BMI as these are parameters that are routinely recorded prior to surgery, without further cost, time, or radiation risk to the patient. Chest X-rays cannot accurately and reliably be used to measure the ICD as it would lead to variability according to the magnification of the X-ray, the position of the patient and the precise angle at which the X-ray is taken. CT scanning carries the risk of allergic reactions to the contrast medium, nephrotoxicity from contrast, and radiation exposure which is higher for the recipient site (thorax) than for the donor site (abdomen) including exposure of the contralateral breast and thyroid to radiation.[29] Although Tuinder et al.[23] suggest using MRI to image the recipient site when it is already being performed for staging of breast cancer, this still involves the use of a contrast medium. Contrast-enhanced magnetic resonance angiography (MRA) has been reported as an alternative method of imaging the flap vessels, with better delineation of the perforator venous system, absence of ionising radiation, and a better side-effect profile of the contrast agents used compared to CT angiography.[30] However, both these methods of imaging present risk and inconvenience to patients, are dependent on skilled operators and surgical interpretation/correlation to give meaningful results and have cost implications for the health provider. Ultrasound may represent an alternative source of preoperative information, with good concordance between ultrasound and surgical findings.[23,31]

Our study has several limitations. First, the data only apply to vessel exposure in the second intercostal space. Literature reports use of both the third and the second intercostal space for vessel exposure for breast reconstruction with a free flap. The senior author (C.M.M.) prefers to use the second intercostal space, as this is usually cranial to the confluence of the vein exposing a larger caliber vessel than in the third space, and there is still reasonably easy access through the mastectomy wound.[6] This preference was recently supported by the work of Tuinder et al.[23] who demonstrated that the second space was significantly larger than the third by a mean of 4.4 mm on the right and 4.5 mm on the left. However, many surgeons still use the third intercostal space for vessel exposure, and our results cannot be directly extrapolated to the third space. Secondly, this study showed no increase in complications with smaller ICDs and no statistically significant correlation between ischemia time and ICD. However, the overall rate of complications was low in this consecutive series of the first 3 years of exclusive use of the total rib-sparing approach to IMV exposure (reexploration rate of less than 1% with a 100% flap success rate). All IMV dissections were supervised by a single experienced microvascular surgeon, with particular expertise in breast reconstruction using total rib-sparing vessel exposure. For the experienced surgeon, variations in the ICD may not cause any problems, but for a surgeon learning the rib-sparing technique, it is plausible that performing an anastomosis in an intercostal space of 13 mm may lead to more complications than in a space of 29 mm. In those cases where the ICD is very narrow and it is technically not possible to perform the anastomoses, we would suggest nibbling the second or third costal cartilage in increase the intercostal space for the anastomoses or convert to a rib-sacrificing technique if necessary. Neither of these were needed in our series. The ischemia times recorded did not differentiate the experience level of the microsurgeon, with trainee microsurgeons given the opportunity to perform the microanastomoses when the ICDs were more favorable. This probably affected the expected negative correlation between ischemia time and ICD (although this was unlikely to affect complication rate).[32,33] Lastly, a further caveat is that the mean height of British women is 162 cm (Health Survey for England 2010, age bracket 45–54 years) whereas the mean height of women in our study was 165 cm (mean age 51 years).[34] This is across all ethnicities; anecdotally, our population was majority Caucasian and the findings may not apply to women from nonCaucasian ethnic backgrounds.

CONCLUSIONS

Total rib-sparing IMV exposure has undoubted benefits for the patient. Its increasing use has made the ICD pertinent to microsurgical breast reconstruction. Although it seems intuitive to use height as a proxy for ICD there was no correlation between height and ICD in our consecutive series. The anatomy of the intercostal spaces is variable and was not predictable in relation to height, BMI, or age. Being able to identify patients with a small ICD in whom microsurgery may be more challenging allows thorough preoperative surgical planning. For the less-experienced surgeon, we would advocate preoperative imaging of the recipient intercostal space and IMVs to determine whether the patient is suitable for rib-sparing vessel exposure. In certain patients, the benefits of preoperative CT angiography may outweigh its risks, otherwise we would suggest ultrasonography for this purpose. This study found no correlation between ICD and flap ischemia time or complication rate thus highlighting the safety of the rib-sparing IMV exposure technique.

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