How to assess the volume of a DIEP flap using a free online calculator: the DIEP V (volume) method☆☆☆,☆☆☆☆

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Title

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Running Head

The DIEP V

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SUMMARY

Introduction: Among the few methods available, none is able to determine accurately the volume of a DIEP flap. Specimen weight is commonly used to assess the amount of flap needed to reconstruct a breast, but the density of breast is different from that of abdominal tissues; therefore, the volume should be used as a unique unit of measure. The purpose of this study was to provide a simple method to calculate the predicted volume of a DIEP flap in order to match the volume of the breast being reconstructed.

Material and Method: We hypothesised that the shape best resembling a DIEP flap was a truncated pyramid. Based on this shape, we tailored 30 DIEP flap models using the discarded tissue after unilateral DIEP flap breast reconstructions. The awaited volume (AV) of the models was calculated with a free online calculator measuring the length and height with a ruler, and width (fat thickness) with Ultrasound (US).

The real volume (RV) of the models was calculated using water displacement method. AV and RV were compared and statistical analysis was performed.

Results: The mean difference between the AV and the RV was not statistically significant with a mean estimation error of 6.75%. When the AVs were plotted against the RVs, the two data sets were highly statistically correlated (correlation coefficient (r) = 0.997).

Conclusions: The proposed tool can be a useful, precise, easy and accessible tool to improve the current DIEP flap size assessment improving outcomes for both surgeons and patients.

Keywords: Microsurgery; Breast reconstruction; DIEP; DIEP volume; DIEP shape.

INTRODUCTION

DIEP flap indications are restricted to those patients having enough abdominal tissue to reconstruct a breast and where primary closure of the donor site can be performed. The estimation of the amount of tissue needed to reconstruct a breast using a DIEP flap can be challenging, but it is crucial to guide the pre-operative and intra-operative planning. At present, the evaluation of the amount of abdominal tissue available relies mostly on experience; the assessment of subcutaneous fat availability has been described using Materassoôs manoeuvre or the ópinch testô method [1] and finally using CT based calculations [2]. Among the few methods available, none is able to determine accurately the volume of a DIEP flap with zone IV being discarded. As a result, the final breast cup size and the possibility of reducing the contralateral breast are sometimes left entirely to the surgeon and the patient may lack understanding. The purpose of this study was to provide a simple method to calculate the predicted volume of a DIEP flap in order to match the volume of the breast being reconstructed.

MATERIAL AND METHOD

We hypothesised that the geometrical shape best resembling a DIEP flap is a frustum with a square base, also known as a truncated pyramid (Fig 1). This shape is a square-based pyramid with its vertex cut by a plane parallel to the base. This model was chosen as it is the shape of a DIEP flap following zone IV being discarded, taking into consideration the difference in fat thickness from the periumbilical area to the point corresponding to the anterior projection of the external oblique muscle [3-4].

Using the contralateral abdominal tissue which would usually be discarded in unilateral breast reconstructions, we tailored 30 DIEP flap models in different sizes, centred on pre-operative ultrasound (US) measurements and shaped to fit a typical DIEP flap (Fig 4).

We collected obtainable measurements and calculated the volume of DIEP models. The length (a) and width (b) are measurements taken at the base of the truncated pyramid, at the level of the medial aspect of the flap. The length (c) and width (d) are measurements taken at the top of the truncated pyramid, at the level of the lateral aspect of the flap. The final measurement, height (h), is the distance from the base to the top of the frustum (Fig 2). The lengths (a and c) and height (h) measurements were taken on the skin surface with a simple ruler after having drawn the truncated pyramid shape of the DIEP model. The widths (b and d) are measurements of fat thickness; they were obtained pre-operatively with US imaging and confirmed intra-operatively with a ruler, and these were taken as the final thickness value.

When measuring abdominal fat thickness with a US probe, it is important to push the probe very gently on the skin in order to avoid compressing the fat, thus reducing the risk of false thinner thickness reading (Fig 3).

Using the values measured on the skin surface (a, c and h) and the fat thickness (b and d), the AV volume of the flap can then be calculated using the polynomial formula available as a free online calculator at: http://www.aqua-calc.com/calculate/volume-truncated-pyramid [5].

The RV of the flap was calculated using a water displacement method intra-operatively. The flap model was immersed in a container with a scale, filled with 500 ml of saline. The RV was represented by the difference between 500 ml and the volume after the saline displacement. The weight (m = mass) of each model was also recorded. The Density (ρ) of the model was calculated using the formula $\rho = m/V$. The data were collected prospectively in an excel spreadsheet. The AV was compared to the RV of the flap and statistical analysis was performed. Data were evaluated to provide the mean difference in volume, giving mean estimation error (%) and the correlation coefficient (r) demonstrating the relationship and proximity between the AVs and RVs.

RESULTS

Thirty DIEP flap models were included in the study, and all the data were collected prospectively. The mean weight of the flap models was 297g (range: 89-869g) and the mean density was 0.84 (range: 0.76-0.91). We found the mean real flap model volume to be 353.3 ± 252.0 s.d. (range: 105-1050cc) and the mean awaited flap model volume to be 358.8 ± 268.3 s.d. (range: 113-1092cc). This resulted in a non-statistically significant mean difference in volume of 21.7cc and a mean estimation error of 6.75% (SD: 15.5, *p*-value: 0.27) (Table 1).

When the AVs were plotted against the RVs, the correlation coefficient (r) was 0.997 (95% CI: 0.993-0.998) demonstrating a highly statistically significant correlation between the two data sets (Fig 5). A two-tailed Pearson correlation was also performed, investigating the correlation between the RVs and the percentage difference between RVs and AVs (cc). A correlation coefficient r = -0.4 (p=0.28) demonstrated a negative correlation between these two variables (Fig 6).

DISCUSSION

Mohanna and Farhadi [1] have been the first to describe a manual method to assess the hypothetical abdomen volume considering the DIEP flaps as two identical triangles and measuring the thickness of the abdominal skin and fat using a metal caliper. Nanidis and colleagues [2] assessed the volume of a triangular shaped DIEP flap using the routine pre-operative computed tomography angiogram (CTA) scan. They converted it into weight rounding the specific gravity of the subcutaneous fat (0.907g/cm[3]) up to 1 for simplicity purposes and considered intra-operative champhering as compensation for the tissue discarded from zone IV.

The first point of our research was to improve the accuracy of the shape of the flap model with the correct assessment of fat thickness. Recent studies revealed that there is a noticeable difference in the fat thickness along different areas of the abdomen [3-4]. These findings support the fact that the final shape of a DIEP flap is not an isosceles triangular prism, but, when cranial champhering of the flap is not performed and zone IV is discarded, the final shape best resembles a truncated pyramid. This is particularly important in thin patients with small amount of fat underneath Scarpaôs fascia that are not suitable for cranial champhering of the flap. Fat thickness can be assessed with different methods [1-2]; we feel that US imaging can yield the same fat thickness as predicted by applying our formula. In our centre, we have been using pre-operative doppler sonography for 10 years to obtain information on the position of the best perforator vein. Since October 2014, multiple-point abdominal fat thickness measurement has also been requested in order to complete the donor site evaluation. US is easy, portable, reproducible and can be used in clinics; on the other hand, the flap thickness can also be calculated using pre-operative CTA.

As the Breast V formula was developed to reduce the chances of incorrect breast volume estimation [6], the second point of our study was focusing on the volume as the unique objective unit of measure. In immediate reconstructions, a common method to match a DIEP flap to the breast being reconstructed is the comparison between the specimen weight and the flap weight; unfortunately, this method leads to incorrect results because specimen weight and flap weight have different volumes. In delayed reconstructions, the amount of flap needed mostly relies on surgeonôs experience. For these reasons, we strongly suggest that the volume of the flap should to be calculated, rather than its weight. The volume formula is V=m/ɉ (mass or weight /density). The key point is the fact that the density of breast tissue differs from that of abdominal tissue. The breast is composed of glandular tissue, fat and skin, while the autologous tissue used to reconstruct a breast is composed only of fat and skin. Furthermore, as proved by Vanderweyer in 2002, the composition of the breast varies from patient to patient, and the ratio between fat, glandular tissue and skin differs widely from one breast to another. They found differences in breast density ranging from 0.84 to 1.15 with a mean of 0.99 [7]. DIEP flap density in our series ranged from 0.76 to 0.91 with a mean of 0.84.

The mean percentage difference between AV and RV in our study was 6.75% with a correlation coefficient r = 0.997 (95% CI: 0.993-0.998), demonstrating an accurate method of calculating the volume. The mean percentage of error is low and this is reinforced by a very high correlation coefficient. We can ascertain that our value of 0.997 demonstrates a near perfect correlation, hence proving that the difference between the two data sets is minimal. [8]

The correlation coefficient r =-0.4 (p=0.28) of the two-tailed Pearson test demonstrated a negative correlation between the RVs and the percentage difference between RVs and AVs. The scatter graph highlighted that as the RV of the models increases, the percentage difference between the RV and the AV tends to decrease. (Fig 6) This means that for the RV model data, in the range of volumes of a standard DIEP (300 to 1050 cc), our method becomes even more accurate (Fig 6).

Another method to plan the volume of a DIEP flap according to the most suitable perforators has been recently described, allowing including flap volumes within a virtual DIEP flap planning using a 3D stereophotogrammetry. Such a tool might not be available in every centre performing autologous tissue breast reconstruction. Sometimes an easy idea might be the most effective one; therefore, we think of our method as a practical tool needing only a portable US, a ruler and a marking pen to plan the desired reconstruction in no more than 5 minutes with a proven accuracy.

Furthermore, with our model, it is also possible to predict variations of the volume when adding or taking off centimetres to different edges of the flap, thus allowing volume adjustments when the flap is shaped to match to contralateral breast volume.

A given example is where a flap of 424cc has been harvested with the following measurements: a = 12cm, b= 4cm, c = 8cm, d = 3cm, h = 12cm. If the flap needs to be reduced to 361cc, h can be reduced from 12cm to 10cm discarding tissue from the lateral aspect of the flap, subsequently increasing c to 8.6 cm. This leaves a flap with an appropriate volume for reconstruction.

Although a simple US is needed to calculate the fat thickness parameters, this information can easily be obtained during pre-operative Duplex Scan or on CT scan images in the centres which use CTA as pre-operative investigation. When implemented in practice, this technique might even be applied without any pre-operative study, by measuring flap thickness intra-operatively, to fulfil the needs of those fancy old school surgeons who still do not perform CTAs or MRIs and just rely on hand-held dopplers for a DIEP flap.

A precise assessment of the volume of a DIEP flap before surgery allows the surgeons not only to better plan their operation, but also to counsel the patient and manage their expectations in the clinic setting. Therefore, the patient can be informed about the amount of tissue available for breast reconstruction, and if necessary, the need for contralateral breast reduction can be discussed. Furthermore, knowledge of available abdominal tissue will help in cases such as bilateral reconstruction or where a bipedicled flap is being considered when a large breast is being reconstructed or a single DIEP would not provide enough volume.

CONCLUSIONS

Our data show that using the DIEP V method, we can accurately measure the volume of a DIEP flap both pre-operatively and intra-operatively.

This can improve the current volume/weight assessment used to evaluate DIEP flaps in many institutions and can provide a useful tool which is precise and accessible. An accurate estimation of the volume of a DIEP flap can be obtained with an easy, reproducible and affordable method, thus improving outcomes for both surgeons and patients.

Acknowledgements and Contributions

SR Main Idea, conducting the study, DIEP models tailoring and evaluation and data collection, statistical analysis, review of literature, writing and editing of the article.

RT Review of literature, writing the article and drawing.

FS comparison between breast density and DIEP flap density, editing of the article.

AF Coordination of the study, editing of the article, final review.

Conflict of Interest: NONE

Funding: NONE

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Figure Legend

Fig 1. DIEP flap model schematic 3D representation. The geometrical shape best resembling a DIEP flap is a truncated pyramid. A Truncated pyramid or frustum of a pyramid is a pyramid whose vertex is cut away by a plane parallel to the base.

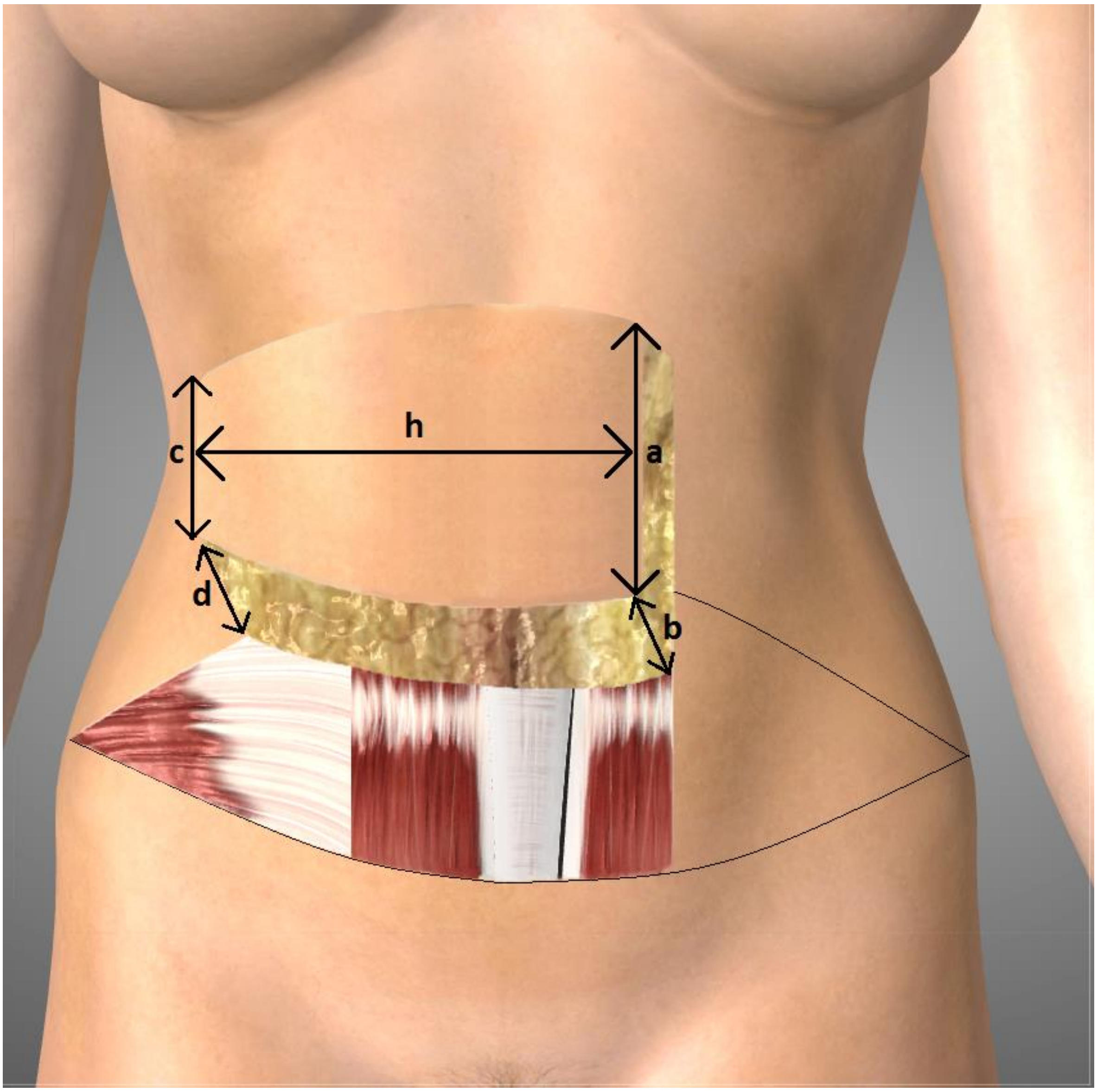
Fig 2. a) Schematic representation of proposed geometrical shape (truncated pyramid) as applied to abdomen when planning DIEP flap. b) Demonstration of truncated pyramid shape including labelled edges required to calculate volume. c) Formula for calculating volume of truncated pyramid.

Fig 3. Ultrasound guided fat thickness

Fig 4. DIEP V flap model measurements: The length (a) and fat thickness (b) at the base of the truncated pyramid, at the level of the medial aspect of the flap. The length (c) and fat thickness (d) are measurements taken at the top of the truncated pyramid at the level of the lateral aspect of the flap. Height (h), is the distance from the base to the top of the frustum. The awaited volume is calculated with the [http://www.aqua-calc.com/calculate/volume-truncated-pyramid] online calculator. The real volume is calculated by volume displacement method.

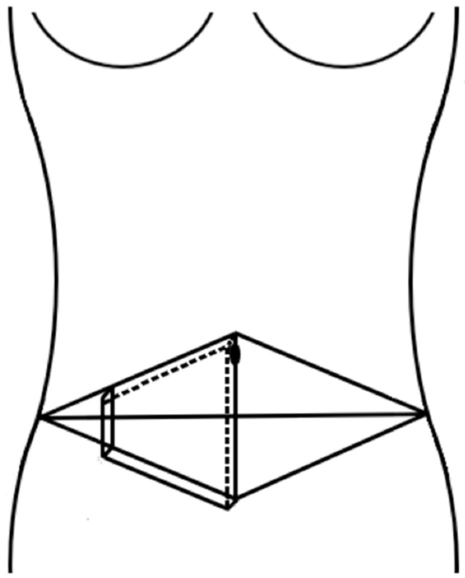
Fig 5. Correlation coefficient (r) of awaited volume (x) against actual volume (y)

Fig 6. Two-tailed Pearsons correlation test between the RVs and the percentage difference between RVs and AVs and scatter graph.

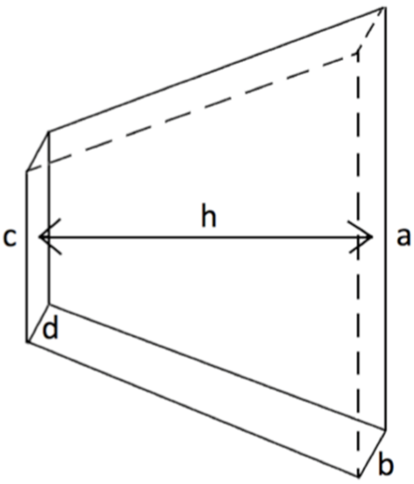


h
c
a
d
b

a)

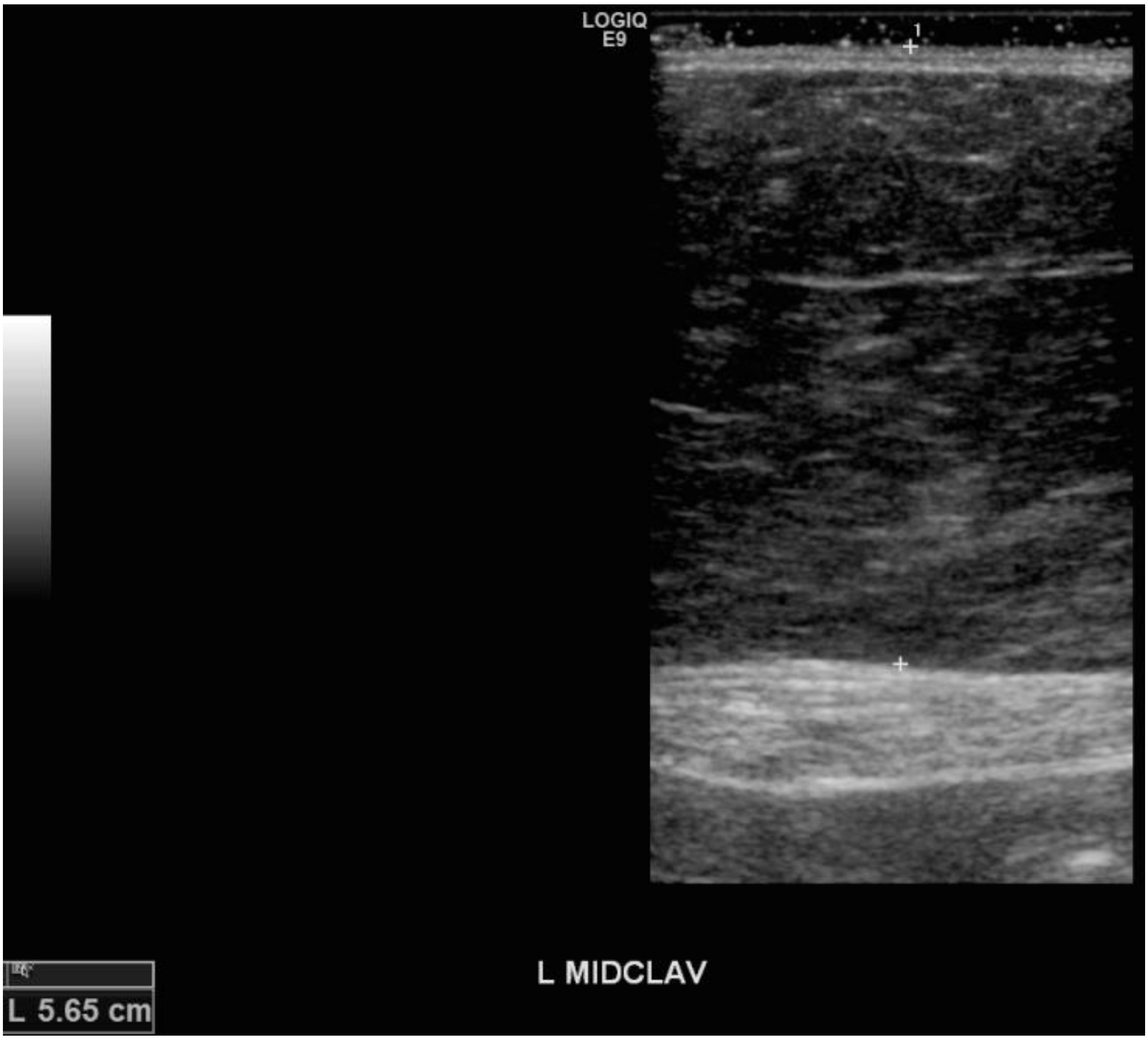


b)

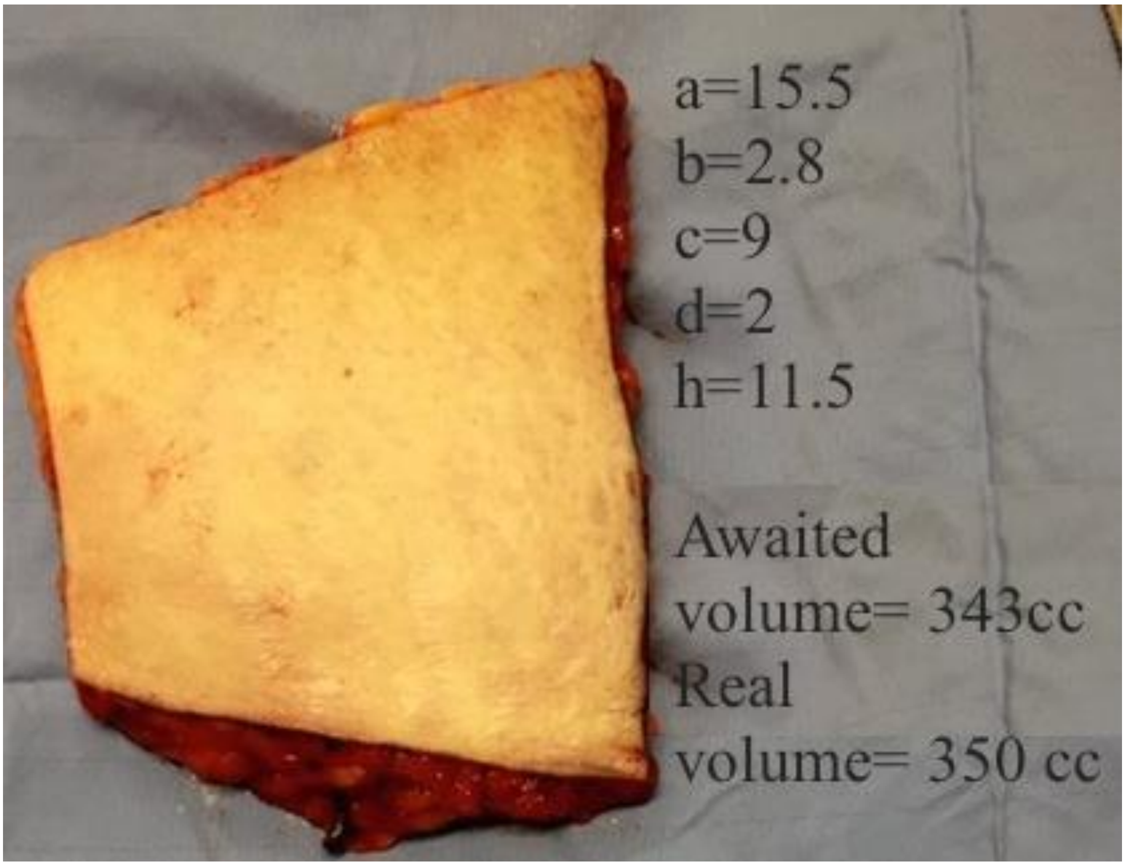


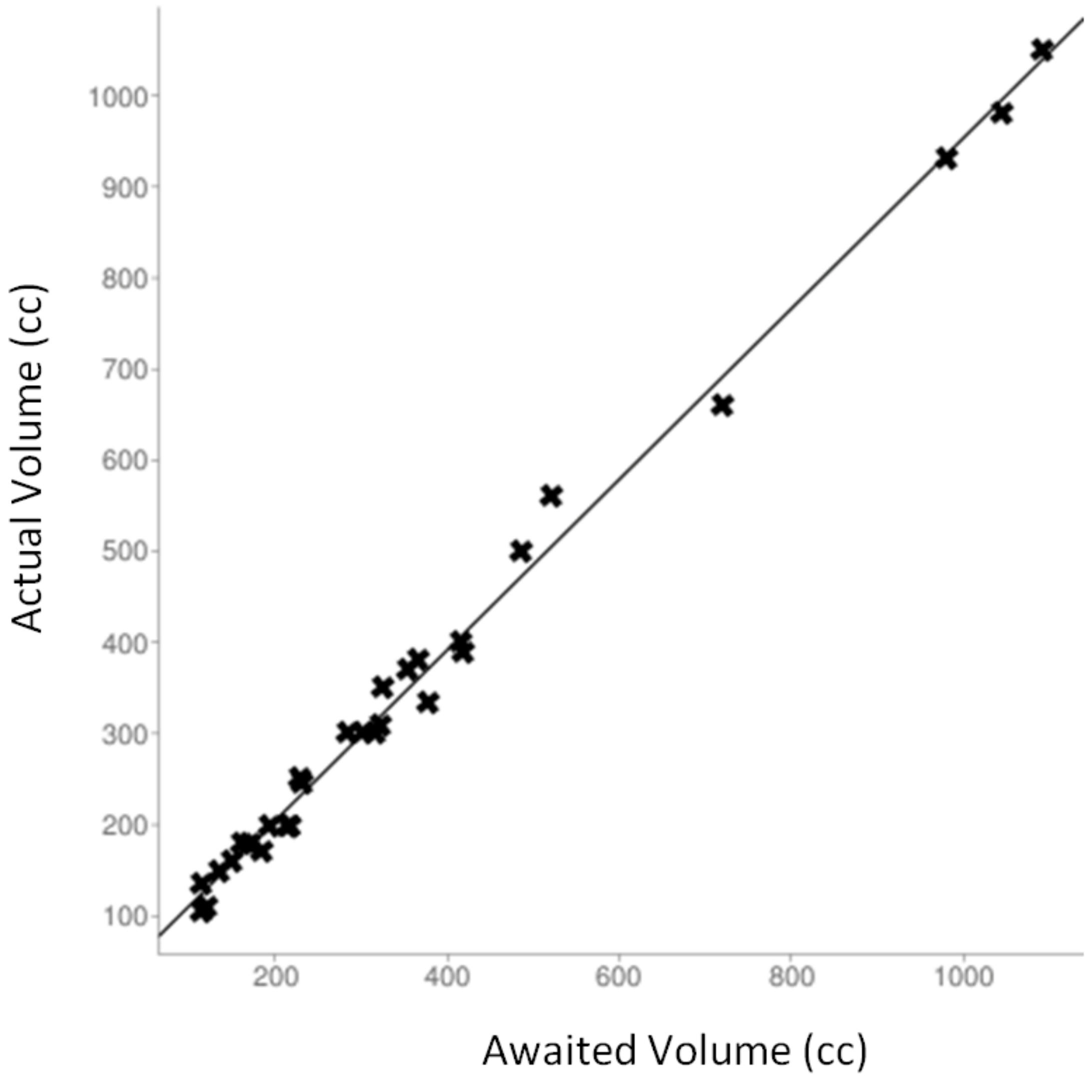
c)

$$\text{Volume of A Truncated Pyramid} = \frac{h\,(ab+(a+c)(b+d)+cd)}{6}$$



LOGIQ
E9
1
L MIDCLAV
L 5.65 cm


a=15.5
b=2.8
c=9
d=2
h=11.5
Awaited
volume= 343cc
Real
volume= 350 cc



Actual Volume (cc)
1000
900
800
700
600
500
400
300
200
100
200
400
600
800
1000
Awaited Volume (cc)

Correlation between Real Volume and Percentage difference between Real volume and awaited volume

		Real_volume	Percentage_difference
Real_volume	Pearson Correlation	1	-.400*
	Sig. (2-tailed)		.028
	N	30	30
Percentage_difference	Pearson Correlation	-.400*	1
	Sig. (2-tailed)	.028	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

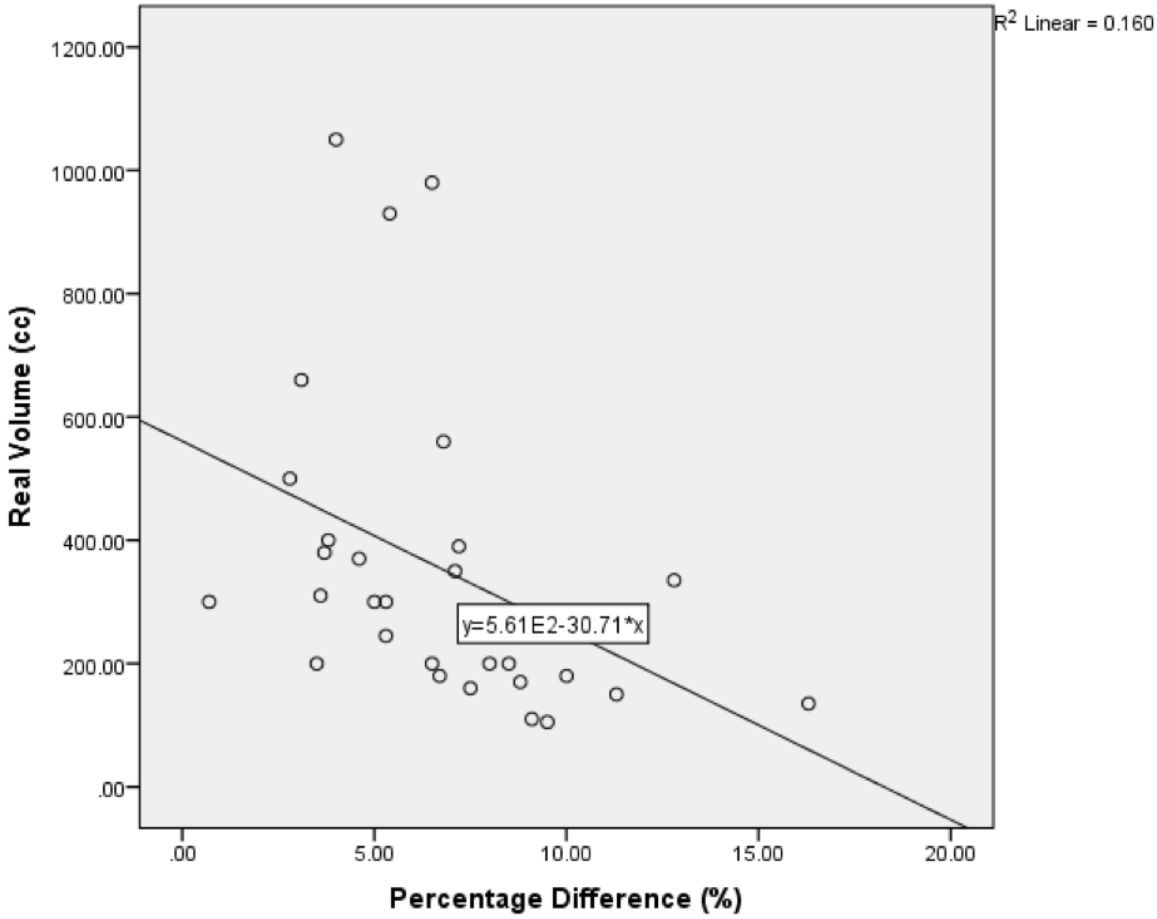


Table 1. Data collection from 30 DIEP flap models

Patient	Awaited Volume (cc)	Real Volume (cc)	Difference (cc)	Difference (%)	Weight (g)	Density
1	113	135	-22	16.3	105	0.78
2	168	180	-12	6.7	148	0.82
3	284	300	-16	5.3	258	0.86
4	378	335	+43	12.8	276	0.82
5	1044	980	+64	6.5	811	0.83
6	486	500	-14	2.8	415	0.83
7	1092	1050	+42	4.0	869	0.83
8	325	350	-25	7.1	296	0.85
9	353	370	-17	4.6	336	0.91
10	217	200	-17	8.5	170	0.85
11	185	170	+15	8.8	139	0.82
12	193	200	-7	3.5	174	0.87
13	120	110	+10	9.1	89	0.81
14	148	160	-12	7.5	134	0.84
15	232	245	-13	5.3	200	0.82
16	366	380	-14	3.7	331	0.87
17	980	930	+50	5.4	745	0.80
18	522	560	-38	6.8	453	0.81
19	162	180	+18	10.0	156	0.87
20	418	390	+28	7.2	305	0.78
21	216	200	+16	8.0	180	0.90
22	115	105	-10	9.5	90	0.86
23	415	400	+15	3.8	340	0.85
24	315	300	+15	5.0	265	0.88
25	720	660	+80	3.1	578	0.88
26	213	200	+13	6.5	180	0.90
27	302	300	+2	0.7	268	0.89
28	321	310	-11	3.6	276	0.89
29	133	150	-17	11.3	120	0.80
30	227	250	-23	9.2	190	0.76
Mean	**358.8**	**353.3**	**21.7**	**6.75**	**297**	**0.84**
			***p*-value 0.27**			