Evaluation of three-dimensional computed tomography processing for deep inferior epigastric perforator flap breast reconstruction

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BACKGROUND: The deep inferior epigastric perforator flap procedure has become a popular alternative for women who require breast reconstruction. One of the difficulties with this procedure is identifying perforator arteries large enough to ensure that the harvested tissue is well vascularized. Current techniques involve imaging the perforator arteries with computed tomography (CT) to produce a grid mapping the locations of the perforator arteries relative to the umbilicus.

OBJECTIVES: To compare the time it takes to produce a map of the perforators using either two-dimensional (2D) or three-dimensional (3D) CT, and to see whether there is a benefit in using a 3D model.

METHODS: Patient CT abdomen and pelvis scans were acquired from a GE 64-slice scanner. CT image processing was performed with the GE 3D Advantage Workstation v4.2 software. Maps of the perforators were generated both as 2D and 3D representations. Perforators within a region 5 cm rostral and 7 cm caudal to the umbilicus were measured and the times to perform these measurements using both 2D and 3D images were recorded by a stopwatch.

RESULTS: Although the 3D method took longer than the 2D method (mean [± SD] time 1:51±0:35 min versus 1:08±0:16 min per perforator artery, respectively), producing a 3D image provides much more information than the 2D images alone. Additionally, an actual-sized 3D image can be printed out, removing the need to make measurements and producing a grid.

CONCLUSIONS: Although it took less time to create a grid of the perforators using 2D axial CT scans, the 3D reconstruction of the abdomen allows the plastic surgeons to better visualize the patient's anatomy and has definite clinical utility.

Key Words: *3D; Breast; Computed tomography; Deep inferior epigastric perforator; DIEP; Reconstruction; Three-dimensional*

Évaluation de la tomographie tridimensionnelle par ordinateur pour la reconstruction mammaire par lambeau perforant épigastrique inférieur

HISTORIQUE : La technique du lambeau perforant épigastrique inférieur est devenue une solution de rechange populaire chez les femmes qui ont besoin d'une reconstruction mammaire. L'une des difficultés de cette technique est l'identification des artères perforantes de calibre suffisant pour que le tissu prélevé soit bien vascularisé. Les techniques actuelles reposent sur l'imagerie des artères perforantes au moyen de la tomographie par ordinateur pour produire une carte de leur localisation par rapport à l'ombilic.

OBJECTIFS : Comparer le temps requis pour générer une carte des perforantes à l'aide de la tomographie bidimensionnelle (2D) ou tridimensionnelle (3D) et vérifier s'il y a lieu de privilégier le modèle 3D.

MÉTHODES : Des tomographies de l'abdomen et du bassin des patientes ont été acquises au moyen d'un appareil GE 64. Le traitement de l'image a été réalisé au moyen du logiciel GE 3D Advantage Workstation v4.2. Les cartes des artères perforantes ont été générées sous forme de représentations 2D et 3D. Le calibre des artères perforantes situées à 5 cm (rostral) et 7 cm (caudal) de l'ombilic a été mesuré et le temps d'exécution de ces mesures à l'aide des images 2D et 3D a été chronométré.

RÉSULTATS : Bien que la méthode 3D ait pris plus de temps que la méthode 2D (temps moyen [É.-T.] 1:51 ± 0,35 minutes, contre 1,08 ± 0,16 minutes par artère perforante, respectivement), la génération de l'image 3D donne beaucoup plus d'informations que l'image 2D seule. De plus, une image 3D grandeur nature peut être imprimée, ce qui élimine le relevé des mesures et à la production d'une grille.

CONCLUSION : Bien que la production d'une grille des perforantes ait pris moins de temps avec la tomographie axiale 2D, la représentation 3D de l'abdomen permet au plasticien de mieux visualiser l'anatomie de la patiente et revêt une utilité clinique indiscutable.

One in eight women will develop invasive breast cancer during her life. Many of these women will choose to remove a part of the breast or have a mastectomy (1). The deep inferior epigastric perforator (DIEP) flap procedure is quickly becoming a popular breast reconstructive option for women who will or have undergone mastectomies. The DIEP flap consists of autologous tissue from the abdominal area. Skin, fat and vessels are harvested while the underlying rectus abdominis muscles are left in place (2). As a result, the risk of abdominal weakness and hernias is reduced (3).

During the DIEP procedure, the surgeons must ensure that the tissue they harvest is well-vascularized to prevent tissue necrosis. The DIEP flap is supplied by the deep inferior epigastric artery, which originates from the external iliac artery slightly rostral to the inguinal ligament, and its branches perforate through the rectus abdominal muscles (4). While some

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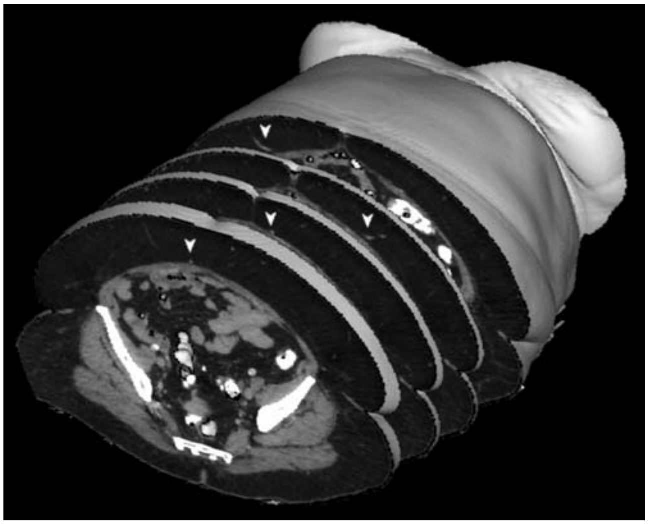

Figure 1) *Two-dimensional computed tomography slices for identifying perforator arteries*

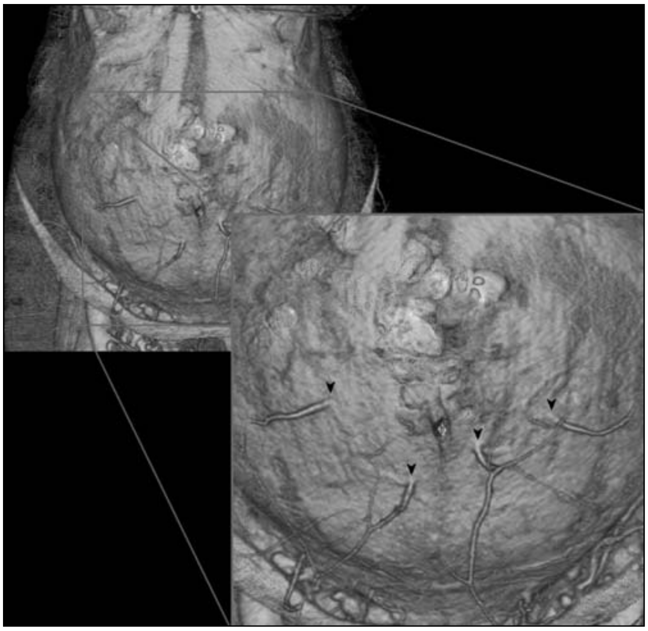

Figure 2) *Three-dimensional model for identifying perforator arteries*

surgeons may choose to find the perforator arteries intraoperatively, there are many advantages in locating the arteries preoperatively. By mapping the locations of the arteries on a grid, using the umbilicus as the origin, the surgeons have a better idea of what they will see as they lift the skin flap. Additionally, measuring the caliber of perforator arteries preoperatively allows the surgeon to decide which region of tissue to use based on vascularization (5).

Current methods of imaging the abdomen include Doppler ultrasound and computed tomography (CT) (5). The goal of the present project was to produce a map of the perforator arteries using either two-dimensional (2D) or three-dimensional (3D) CT, and comparing the two methods to determine which is faster. Additionally, we will determine whether there is any added benefit in producing a 3D image of the abdominal anatomy.

METHODS

Patient CT abdomen and pelvis scans were acquired from a GE 64-slice scanner and accessed from Picture Archive and Communication System (GE Healthcare, USA). Slice thicknesses were either 0.625 mm or 1.25 mm. CT image processing was performed with the GE 3D Advantage Workstation v4.2 software (GE Healthcare, USA). Processed 3D images were printed on 35 cm × 43 cm Kodak DryView Laser Imaging Film (Kodak, USA) using a GE DryCam Laser Imager printer. Time measurements were obtained with a stopwatch.

Twenty-five patients who had been given arterial and enteral contrast and scanned by CT in the emergency room were chosen for the present study. Patients were either male or female and older than 18 years of age. For both 2D and 3D image processing, the axial slices were reconstructed using a soft tissue rendering protocol. However, only the respective views (2D or 3D) were used when making measurements. Perforator arteries within a region 5 cm rostral and 7 cm caudal to the umbilicus were measured. All measurements were made in millimeters with the 3D imaging software's distance tool. Timing began after the slices were loaded and ended upon calculating the x- and y-coordinates and the calibers of the perforator arteries.

Processing of 2D CT axial scans required adjusting the window width and level to more easily see the arteries as they perforated through the fascia (Figure 1). The centre of the umbilicus was located and the slice number was recorded. Additionally, an anterior-posterior reference line that displays on all slices was drawn through the umbilicus. In an area 5 cm rostral and 7 cm caudal to the umbilicus, perforators were located and the x-distances were measured with the distance tool relative to the reference line. The slice numbers of the perforators were also recorded. The y-distances were determined by subtracting the slice number of each perforator from the slice number of the umbilicus and multiplying by the slice thickness. Perforator calibers were measured where the arteries perforated through the fascia.

To see the perforator arteries in 3D, some processing was first required. In the surface volume mode, a surface layer two voxels (volumetric pixel) thick was removed (Figure 2). In essence, this is similar to removing the skin from the 3D object. The display was then switched to 3D volume rendering. The opacity was adjusted to hide the subcutaneous fat while clearly displaying the arteries as they perforated through the fascia. The opacity settings were saved as a preset for repeated use during time measurements. A horizontal and vertical line using the distance tool was drawn through the centre of the umbilicus for reference. The option for the distance tool was set to draw a 3D line so that the line would not disappear when rotating the 3D object. Before making measurements, the perforators of interest were located and marked using the report cursor. Measurements were made from an anterior view using the software's distance tool. In this case, the option for the distance tool was set to draw a 2D line. This option is essential to ensure that various anatomical peaks and valleys do not increase the measurements as seen from an anterior view. The 3D model was rotated when measuring perforator calibers for improved accuracy

After processing the 3D images to display the perforator arteries, a life-sized image of the abdomen could be printed. Images were printed in landscape view to make the image as wide as possible. Trial and error was required to determine the

TABLE 1
Time measurements to produce a grid or printout

	2D CT grid		3D CT grid		3D
	Total time	Time per artery	Total time	Time per artery	print out, total time
Minimum	6:28	0:47	5:46	1:11	0:33
Maximum	16:23	1:40	16:50	3:05	1:18
Mean ± SD	9:54±3:00	1:08±0:16	10:07±2:56	1:51±0:35	0:44±0:09

Time presented as min:s. 2D Two-dimensional; 3D Three-dimensional; CT Computed tomography

correct display field of view (DFOV), ie, magnification, based on the print area of the image, but once the DFOV was determined, it was consistent for future printings. Using the software and printer mentioned above, it was determined that the print area was 31.3 cm; however, the DFOV had to be set at 30.8 cm in the software for it to print at 31.3 cm on film. The reason for this mismatch is unknown. Time measurements were made using the preset opacity settings and included the time from when the slices were loaded to when the print button was clicked.

RESULTS

Measuring the perforator arteries' distances from the umbilicus and measuring the perforator calibers using the 2D method took a total time ranging from 6:28 min to 16:23 min (mean [± SD] 9:54±3:00 min), depending on the number of perforators measured. The times for the 3D method ranged from 5:46 min to 16:50 min (mean 10:07±2:56 min). Because some perforator arteries were more difficult to visualize in one method versus the other, the number of perforators measured with each method varied. Thus, a better comparison would be the average time per perforator. The times for the 2D method ranged from 0:47 min to 1:40 min (mean 1:08±0:16 min). The 3D method took slightly longer, ranging from 1:11 min to 3:05 min (mean 1:51±0:35 min). Table 1 summarizes the results.

Producing a grid with the 3D method took more time because of the freedom of rotation when working with 3D objects. Due to shading and the way the 3D object displayed onscreen, some perforators were difficult to see from an anterior view. Additionally, the 3D object had to be rotated to measure the artery calibers as they perforated through the fascia. Although the diameters of the arteries were more easily measured with the 2D method, there is no way to adjust the image to take into account arteries that perforate at an oblique angle. Measurements of these perforators are falsely larger than actuality.

DISCUSSION

Although it took longer to process and measure perforator arteries with the 3D model, this method provided much more information than the 2D CT scans. The 3D model allows the viewer to visualize the perforators as if they were looking at an actual patient. Using 2D slices, the viewer must mentally put the slices together to imagine the locations and paths of the perforators.

An alternative to making measurements and producing a grid is to simply produce a 3D model showing the perforators and printing out an actual-sized image. The amount of time it took to process the image for printing ranged from 0:33 min to 1:12 min (mean 0:44±0:09 min). Measurements of the artery calibers are not required because the plastic surgeon can see the anatomy and determine which perforators are largest. The surgeon can then take this printout, lay it on the patient's abdomen, mark the artery locations on the patient's abdomen, and refer to it during surgery. Essentially, this image provides the same information as a grid, but it takes much less time and also shows the surrounding anatomy and the paths the arteries take superficial to the fascia.

Although it takes less time to create a grid of the perforators using 2D axial CT scans, the 3D reconstruction of the abdomen allows the plastic surgeons to better visualize the patient's anatomy. Not only can the model be rotated in all dimensions, but the paths of the arteries superficial to the fascia can be followed to aid the surgeon with the DIEP flap procedure. Additionally, an actual-sized version of the 3D model can be printed out as a substitution for making the grid. The printout can be placed over the patient's abdomen to mark the location of the perforators as well as provide the surgeon with a visual aid during the procedure.

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