NEFROVOL Organ Reconstruction Method from US Scans for 3D Printing to Better Patient-Physician Relationship: Volume Measurement Accuracy

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INTRODUCTION

For vaguely symmetrical organs, volume measurement is based on pseudo-sphere calculations taking Ultrasound (US) scan "diameters". Some medical conditions nevertheless, such as Poly-cystic Kidney Disease (PKD), greatly deform the organ (Kidney in this case), and therefore only finite elements approximations can render the volume and calculate its value. Contrast media and ionizing radiations (X Rays) of CT scans, are not always suitable due to toxicity and radiation effects. We have developed NEFROVOL, a low cost, non-invasive solution to estimate volume from parallel US images to generate 3D organ models. [1]. The model is 3D printed to be used during the visit with the physician, either full scale or reduced. The volume estimation method is validated here.

METHODS

We have US-scanned vegetables in salt water and obtained their NEFROVOL 3D reconstruction using 5 parallel scans separated by a known distance as guided by an "Epidermic Grid" placed on the water surface [2]. The volumes of the vegetables and of the 3D-printed [3] model were measured by water displacement and compared with NEFROVOL calculations.

RESULTS

Water displacement of a Sweet potato, Sweet pepper, Orange and Potato ranged from 205 to 400 ml. The same objects in water and scanned gave four 3D models by NEFROVOL with volume calculations from 239 to 338 ml, and errors from 2% to 17% whereas the 3D printed model had negligible differences with the software model (errors from 3% to 17%), albeit distributed differently as shown in Table 1.

Table 1. Volume estimation by water displacement, 3D model and NEFROVOL calculation

Vegetables	Cuts	Real (cm^3)	NEFROVOL (cm^3)	Diff. %	3D printed	Diff. %
Sweet potato	8	400	338	-15	340	-15
Sweet pepper	4	205	239	17	235	15
Orange	4	300	307	2	310	3
Potato	5	275	315	15	321	17

As a secondary result of the research, the use of 3D printed organs may be tried in some medical visits, in order to produce a protocol to estimate their impact on patient satisfaction and on patient physician relationship.

DISCUSSION

As expected, a few cuts of a solid contain less geometrical information than the original shape, thus only enabling an approximation of the volume. The number of cuts was limited by the size of the organ (vegetable) and the skin template with 4 to 8 slots for the US transducer. In addition, drawing the organ (or the vegetable) on the US scan distinguishing it from the surrounding tissue (or water containing the vegetables) is performed by hand by the operator with little software aid by NEFROVOL. This is a limiting factor for NEFROVOL method. A performance of 15% to 17% accuracy can only be tolerated in settings where large volume modifications are expected, such as in PKD patients. This accuracy is presently under test in the Nephrology Outpatient Unit as a parallel assessment with regular US scanning. Future work will focus on obtaining two or three additional interpolated cuts between two adjacent scans, by sliding the skin grid and enhancing the software to help identify the organ in its anatomical surroundings.

REFERENCES

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