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3D Modeling Of Lower Urinary Tract to Analyze Lower Urinary Tract Constriction

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ABSTRACT : *CT scan is a basic and very important tool for medical diagnosis. But if we can build a physical model from CT scan data then it can be a very useful tool for medical diagnosis and several medical simulations. This article surveys a promising approach to computer assisted image medical image analysis technique. This analysis combined with extracting the data from CT scan, segmentation and building a 3D physical model from the virtual CT scan data. We have priority knowledge about the size, shape and the location of biological structures. But there is a significant variability of biological structures over time and across different individuals. So these patient specific models will help medical physicians to interpret with the disease more prominently. These CAD model also can be simulated with any fluid-structure interaction analysis and the behaviour of fluid flow san be estimated through this diseased biological organ. In this study a complete methodology, from acquisition of medical images to building the three dimensional model with a particular emphasis on image segmentation was studied. In this study we have developed a 3D CAD model of female Lower Urinary Tract (LUT.*

Keywords *- CT scan, Virtual model, Physical model, Segmentation, Biological model, CAD model, Lower Urinary Tract (LUT)*

I. INTRODUCTION

Urinary tract use to expel our urine in a controlled co-ordinated manner [1]. Having a constriction in urinary tract is not life threatening but it degrades our quality of life, put us into some embarrassing situations. This is the reason for which these researches could not fetch much attention before. Bladder Outlet Obstruction (BOO), constriction in urethra is common in elderly patients, but young patients are also affected. Constriction in lower urinary tract is relatively uncommon then male but it remains a poorly understood condition [2]. The prevalence of constriction in lower urinary tract in women has estimated as 2.7% to 29%. This large variation of estimation happens due to lake of effective and accurate diagnostic technique [3]. A world wide study based on current International Continence Society symptom definitions in adults aged ≥20 year's shows the prevalence of urinary tract symptoms (LUTS), overactive bladder (OAB), urinary incontinence (UI) and bladder outlet obstruction (BOO) is 45.2%, 10.7%, 8.2% and 21.5% respectively. The study has estimated on 2008 worldwide almost 4.3 billion individuals ware affected by at least one of the LUT diseases [4]. So the prevalence of this disease is very high through worldwide. The general symptoms of urethra constriction or bladder outlet obstruction are- painful urination, difficulty in urination, urinary retention, decreased urine flow, increased urgency or frequency, swelling of the penis, testis end scrotum, bloody or dark urine, recurrent urinary tract infection [5]. The common diagnosis techniques are- urine flow rate measurement, Post Void Residual measurement (PVR), urinanalysis [5]. The newest technique is the Urethroscopy where a catheter is inserted assembled with a camera. Some patients also suppress their problem due to fear of invasive analysis [6]. But the complete analysis of the degree of the constriction and the pattern of the constriction is still a challenging task. In this paper the CAD modelling of urinary bladder and the urethra constriction had described. This CAD model is a realistic model for a particular patient. With this study we can diagnose the degree of constriction as well as a complete and accurate overview about the constriction which help surgeons to meet the actual need of clinical treatment.

II. AIMS AND OBJECTIVE

The aim of this study is to obtain a patient specific CAD modelling of lower urinary tract from the CT scan of the patient. The CT scan data would be use here as the input data. The 3D data have to extract from the CT scan by image processing software to make a virtual model of lower urinary tract. From the virtual model with the help of CAD designing software the physical model of lower urinary tract for a specific patient have to make. This physical model could be used for further analysis.

III. MATERIAL AND METHODOLOGY

To make a patient specific 3D model we need CT image of the specific patient of the particular body part. But the procedure discussed here is same in general. CT scan image is a combination of stalks of 2D image slices from which we can extract the 3D information about the particular organ or body part.

TABLE I
DETAILS OF INPUT IMAGE

CT image format	DICOM
Pixel size	0.818
Reduction	1
Number of slices	183
Slice Thickness	0.5 mm
Slice increment	0.2 mm
Gantry Tilt	0.000
Image resolution	512×512
Scanner	SIEMENS/Spirit
Voltage	130KV
Dose	150.00mAs
Exposure time	1000 ms
Institute	INDIAN SCAN/ TAMBARAM/ CHENNAI
Reconstruction algorithm	B20s

Three softwares used here to extract the data from CT scan and to create 3D solid model of urinary bladder i.e. MIMICS, 3-Matic and SolidWork Professional 2010.

A. 3D data extraction from CT

Image processing software MIMICS (Materialise Inc.) was used here to extract the 3D data from the CT scan. MIMICS is capable of extracting the volumetric 3D information by thresholding and image segmentation from the CT scan slices [7]. Thresholding is a process to generate a mask or highlight the area of interest. The biological organs have great discontinuity. Different size and shape for different individual. With a prior knowledge we can only assume that how the shape could be but we can’t take any definite decision. But every biological organ is made up of different type of soft tissues. In CT scan they can be differentiated by their different absorbability of x-ray. As per there absorbability they got different pixel values. Thresholding is a technique to highlight the particular pixel values to differentiate a particular region with others. We can change the threshold profile by drawing the profile line through the urinary bladder at the axial view.

Based on profile line value, which gives the Hounsfield unit variation over the line drawn, thresholding operation was performed to create a mask which connects all the regions of the same threshold range. But the biological organs made up of soft tissues and they have a very small difference in their pixel values. In the process to highlight a particular region, some other unwanted regions also become highlighted. To remove these unwanted regions we have to go through segmentation process.

Segmentation is a process by which we edit the applied mask or the highlighted region and deselect the unwanted regions. We have to edit for each and every slice with the image segmentation tools to create a precise 3D model. Once the segmentation process is over then we have to calculate 3D model for the segmented mask. At the end of the 3D model calculation the virtual 3D model for LUT appeared.

This virtual 3d model will give us the dimension and measurement to create a mechanical model of LUT. A centre line was plotted through the 3D model and polycircles around the 3D model (Fig 3). The centre line will act as an axis of the CAD model and the diameter of the desired area can be measured by the polycircles. In 3-Matic software we can perform the measurement of the LUT. 3-Matic is a software which is the link between the virtual and physical model. 3-Matic allows us to perform basic CAD operations. The model we obtain from MIMICS is already in a very complex, freeform shape. With the help of 3-Matic we can reduce the complexity of the model and convert it in common CAD formats (IGES, STEP, Catia, ProE, Solidworks) that we can use the biological data to create a physical CAD model.

B. CAD modelling

The second step is the Computer Aided Design (CAD) modelling from the virtual 3D data. The model generated using CAD can be used for computational simulations.

The centreline imported into Solid Work Professional as a guide curve. The diameter for a specific region was measured from the MIMICS software. Circles had created into solid work around the centre line at that specific point which acts as the origin of the circle. The centreline has a 3D co-ordinate. So we have to generate a plane at that particular point as a reference geometry on which the circle would be created. These circles are the sketch of the 3D model. Lofted boss/base option or the boundary boss/base option in the solid work can be used to create the solid model. Position of two ureters has also taken from MIMICS. At those points a reference axis and a reference plane created to draw a circle and make a extrude boss/base up to the surface of the urinary bladder. The ureter is the inlet for the urinary bladder. The purpose to create the ureter here is that we can use this CAD model for CFD (Computational Fluid Dynamics) simulation. It will help us to understand the flow of urine through the LUT in a 3D platform. We can also make the diseased model for the urethra constriction by varying the urethra diameter. In case of urethra constriction the constricted portion diameter is less than the normal diameter. So by narrowing the diameter we can create the disease model.

C. Flow chart of data processing

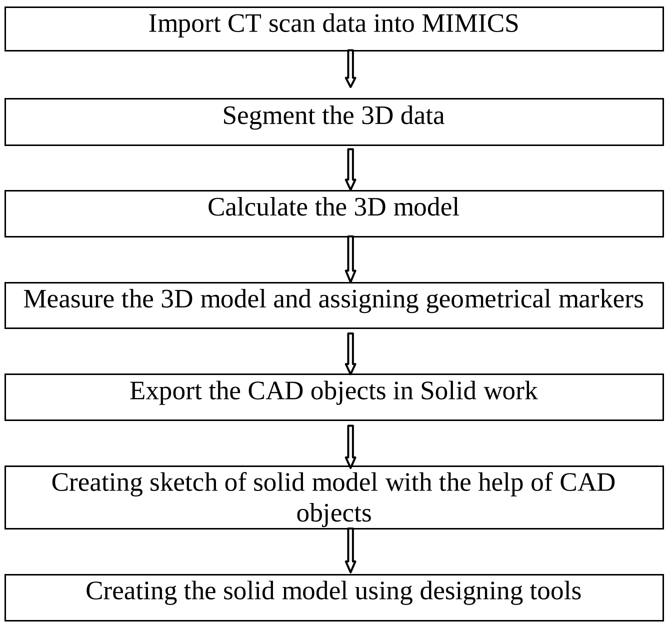


Fig 5: Flow diagram for CAD modeling of Lower Urinary Tract

IV. RESULTS

A. To 3D Model of Lower Urinary Tract

Fig. 2 shows the thresholding operation which has done by drawing profile line. The profile line has drawn on the axial view of the urinary bladder. The graph of the profile line showing the variation of the Hounsfield Unit through over the profile line. Once thresholding has completed a mask has generated over the area of interest. Fig.3 showing a yellow mask have been created after thresholding. Fig. 4 shows the 3D model of LUT consists of urinary bladder, bladder neck and urethra which was obtained by editing the mask.

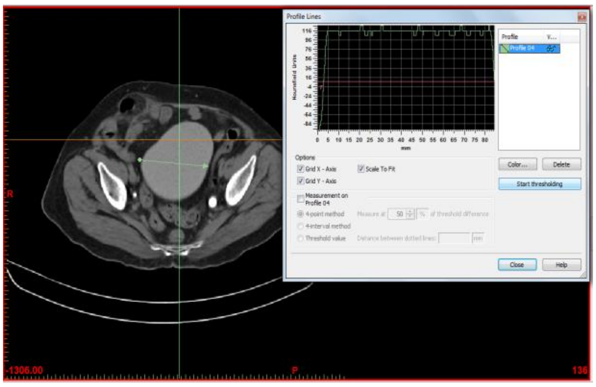


Figure 2: Fig 1: Profile line drawn on axial view

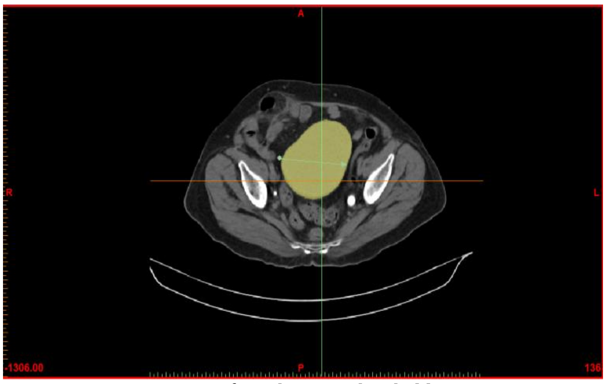


Fig 3: Creation of Mask using Threshold Operation

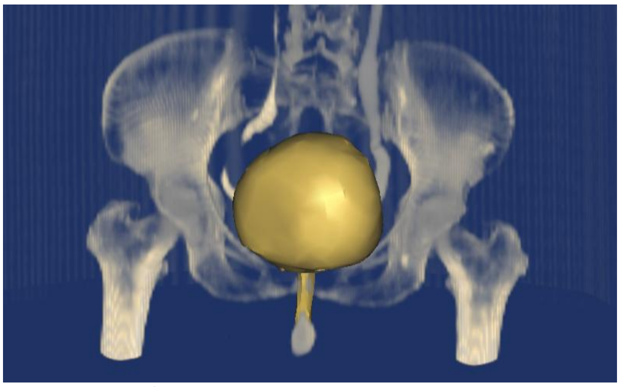


Fig 4: 3D model of Lower Urinary Tract Situated inside the Pelvic Cavity.

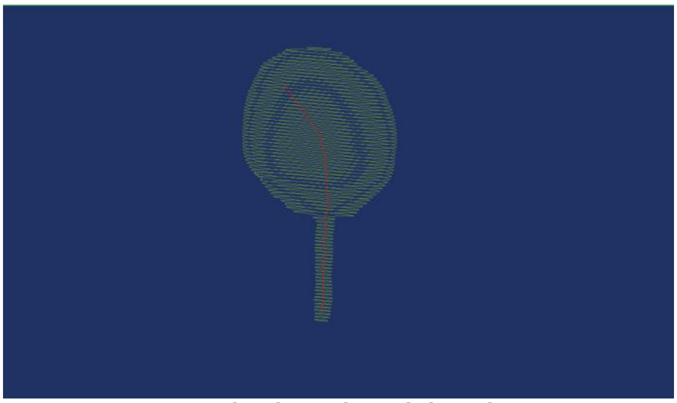


Fig 5: Plotted Centreline and Ploycircles

The geometrical measurement was performed in 3-Matic.

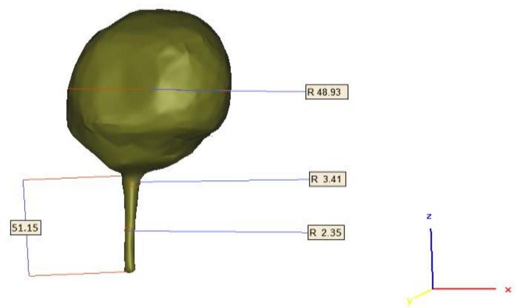


Fig 6: Measurement of Lower Urinary Tract in 3-Matic

This geometrical measurement is compared with the normal value below:

TABLE II
LOWER URINARY SYSTEM MEASUREMENTS [8]

Organ	Length		Diameter	
	Normal	Measured	Normal	Measured
Ureter	25 cm	Not Measured	5 mm	Not Measured
Bladder	-	-	10 cm	97.86 cm
Urethra	4.1±1cm (Female)	5.11 cm	5 mm	4.7 mm
Bladder neck	1.5±5 mm	1.86 mm	6.5±0. 8mm	6.82mm

B. CAD Model of Lower Urinary Tract

The centreline imported into SolidWork as a guide line curve and the circles had constructed around the curve. The 3D sketch of the Lower Urinary Tract has modelled.

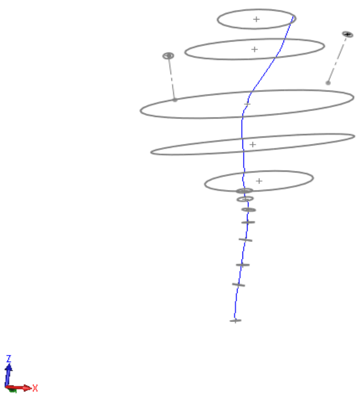


Fig 7: Importing centre line and circle designing into SolidWork

Ureter is the inlet for the urinary bladder. We have introduced ureter in the CAD model. It will help us to simulate this model with fluid flow analysis.

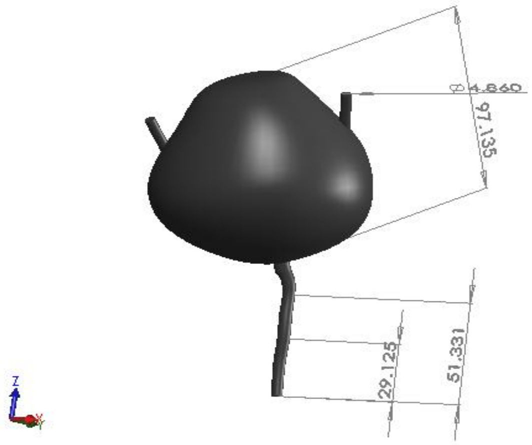


Fig 8: CAD model of normal Lower Urinary Tract

Measurements of CAD model shown in Table No. 3

TABLE III
MEASURE OF CAD MODEL

Organ	Length	Diameter
Ureter	-	4.6mm
Urinary Bladder	-	96.72mm
Urinary Bladder Outlet	-	7.28mm
Bladder Neck	1.71cm	7.25mm
Urethra	5.1cm	-
Urethra Inlet	-	7.2mm
Urethra Middle	-	5.6mm
Urethra Outlet	-	4.86mm

The diseased condition designed here is constriction in urethra. The constriction was created by narrowing the diameter of urethra at a distance of 29.125mm from the urethra outlet. A urethra constriction of 22%, 30% and 50% has shown here from mild to severe case.

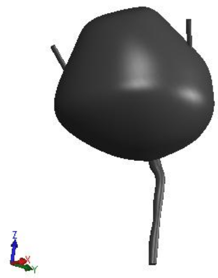
V. DISCUSSION

General procedure to study the urethra constriction is invasive study. Some patients use to suppress their problem due to fear about invasive study. Now a days to determine the degree of constriction and the length of constriction urethroscopy is used. The urethroscopy machine is costly. Then surgeons can find the remedy for the problem. But this procedure gives us more convenient way to diagnose the constriction without any invasive study. A CT scan data gives us an overview about the problem, but these CAD modelling will allow us to determine the outcome of the treatment or surgery. We can work on the CAD model as a real one and we can simulate it to get the desired outcome. It will decrease the manual error in surgery and increase the efficiency with a cost effective way. This is beneficial for patient and surgeon both.

VI. CONCLUSIONS

This study describes CAD design of Lower urinary Tract for a specific patient. This model will also can be simulated with a fluid model and we can determine the urine flow property through the diseased urinary tract. It will allow us to study the original disease condition by altering the fluid property, flow rate and geometry of the CAD model. We can also design the stent for the constriction from the CAD model. The stent model can assemble with the CAD model and that model can be simulated with fluid flow model and we can determine the compatibility of the stent. It will help the surgeons to do the operations flawlessly. To determine the urinary incontinence no standard study is there [7]. But this can be a standard non-invasive study to determine the urinary incontinence if we simulate it properly with a fluid model.

TABLE IV
DISEASE CONDITIONS

	22% constriction, mild condition. Middle urethra diameter reduced to 4.5mm
	30% constriction, Medium Condition. Diameter reduced to 4mm
	50% Constriction, Severe Condition. Diameter reduced to 3mm

VII. ACKNOWLEDGMENT

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