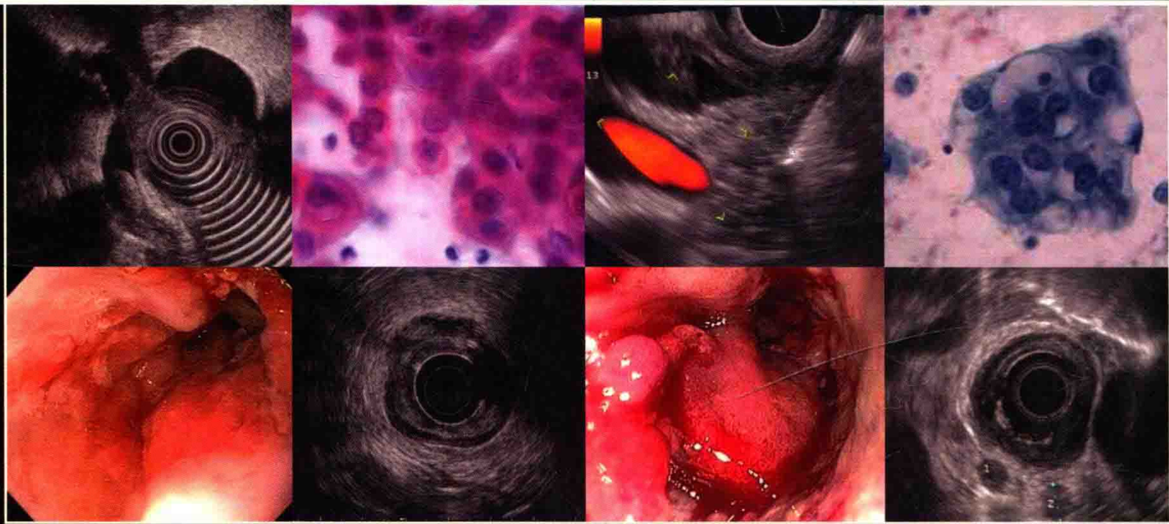
Atlas of Endoscopic Ultrasonography



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Preface

Learning to perform and interpret endoscopic ultrasound (EUS) requires both didactic learning and repetitive exposure to images. We presented detailed aspects of the didactic part of learning in the Gress and Savides textbook *Endoscopic Ultrasonography*. The purpose of this atlas is to allow aspiring endosonographers to visualize numerous examples of images and videos as they improve their pattern recognition of pathologic conditions. Additionally, expert authors have been asked to write a brief, less than 1000 words narrative without references, about the important concepts related to their topics.

This atlas will be of interest not only to those learning EUS, but also those who already perform EUS and want to quickly update their daily use of EUS in terms of diagnosis and therapy. Additionally, the images and videos are in a form which can be easily downloaded from the accompanying DVD in order to give presentations to others.

We are lucky to have added two expert teachers of endosonography, Brenna Bounds and John Deutsch. They bring expertise in EUS video training to the project, as well as contributing significantly from their collections. Without them, this project would not have been possible.

Our contributors are either the "first-generation" pioneers of endosonograpy or "second-generation" protégés of those pioneers. Their collective experience in applying endoscopic ultrasonography in the management of gastrointestinal diseases is unsurpassed. A tremendous amount of effort on the part of each individual author has led to this new atlas. We are deeply grateful to them for their outstanding collaboration.

Frank G. Gress
Thomas J. Savides

Contents

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1 Normal EUS Anatomy

1 Normal Human Anatomy

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Introduction

The Visible Human Project at the University of Colorado has generated large volumes of human anatomy data. The original information is captured by slowly abrading away frozen human cadavers in a transaxial manner and capturing the anatomy by digital imaging. The digital data is compiled and then over the years is manipulated by scientists at the University's Center for Human Simulation to allow access to identified cross sections in any plane as well as to models which can be lifted from the data set. Details regarding the Visible Human Project and its applications to gastroenterology and endosonography have been previously described.

This atlas is fortunate to be able to use the interactive anatomy resources developed by Vic Spitzer, Karl Reinig, David Rubenstein, and others to create movies that help explain what takes place during endoscopic ultrasound (EUS) evaluations. Since EUS is a "real-time" examination, it seems reasonable to present this section primarily as "real-time" videos. The videos can be viewed over and over, allowing endosonographers to look not only at the highlighted structures, but also at structures they might visualize during EUS that are not specifically identified on the selected video.

This chapter uses the terms "radial array orientation" to describe planar anatomy which would be found perpendicular to a line going through the digestive tract (as would be generated by a radial array echoendoscope, Figure 1.1) and "linear array orientation" for planar anatomy generated parallel to a line going through the digestive tract (as would be generated by a linear array echoendoscope, Figure 1.2).

Normal EUS anatomy from the esophagus

Radial array orientation (Video 1.1)

Video 1.1 starts with Visible Human Models of the left atrium (purple), trachea and bronchi (light blue), aorta and pulmonary arteries (red), vena cava (dark blue), and the esophagus (brown). A plane is shown passing through the esophagus. This plane contains the transaxial cross-sectional anatomy images which then follow, starting in the oropharynx and going caudally. The upper esophageal sphincter (UES) is identified. As the images proceed distally, the trachea and esophagus can be followed to a point where the brachiocephalicn left carotid and left subclavian arteries are evident just above the aortic arch. Below the aortic arch is the aortopulmonary window. The azygous arch can be seen exiting the superior vena cava (SVC). This occurs just above the tracheal bifurcation. The esophagus, labeled as "E" is surrounded by the descending aorta, the vertebrae, and the trachea. The thoracic duct (not labeled) is visible between the aorta and vertebrae, inferior to the esophagus. Going distally, the pulmonary artery becomes prominent. The region between the right mainstem bronchus (RMB) and left mainstem bronchus (LMB) is the subcarinal space. The video progresses to a level where the left artrium surrounds the superior aspect of the esophagus and then the video ends as the esophagus passes the gastroesophageal junction.

An image plane cross-section of taken from a radial array orientation at the level of the subcarinal space is shown (Figure 1.3).

Linear array orientation (Video 1.2)

Video 1.2 starts with the same models as above (The left atrium [purple], trachea and bronchi [light blue], aorta and

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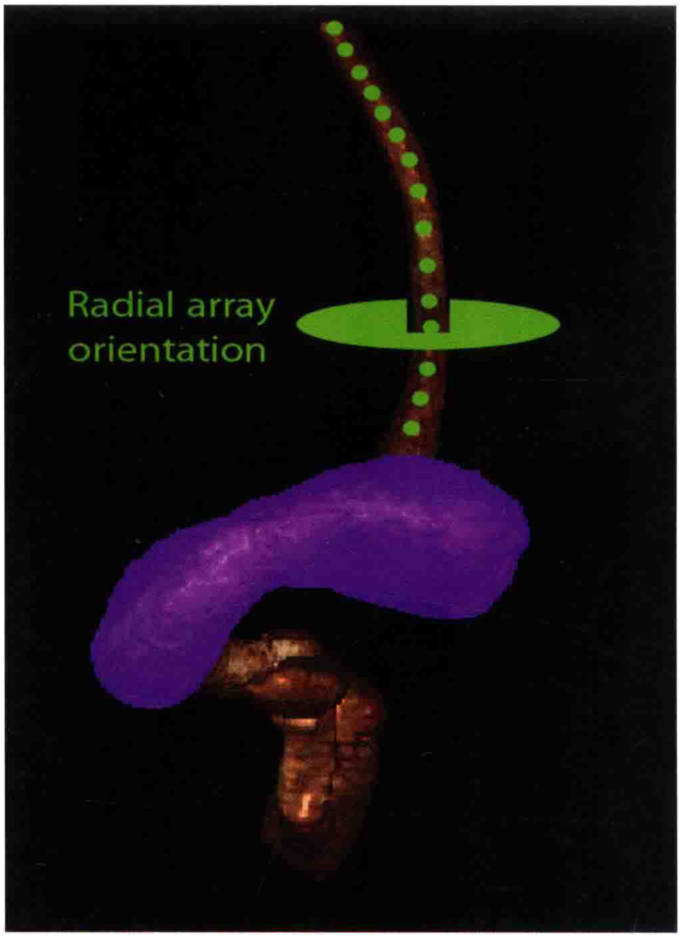

Figure 1.1 Visible Human Model of esophagus, stomach, and duodenum. The green circle shows a plane perpendicular to the axis and is similar to a plane developed during radial array endosonography.

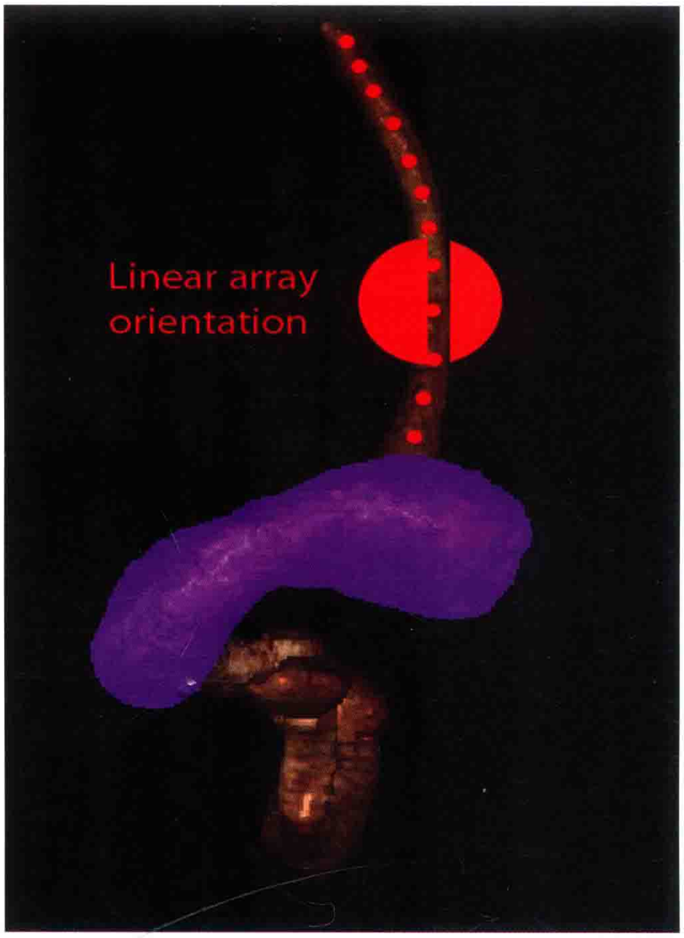

Figure 1.2 Visible Human Model of esophagus, stomach, and duodenum. The red circle shows a plane parallel to the axis and is similar to a plane developed during linear array endosonography.

pulmonary arteries [red], vena cava [dark blue], and the esophagus [brown]). The plane shows potential ways that cross-sectional anatomy can be generated. The video then shows a sagittal image with the descending aorta inferior to the esophagus, much as what is done during linear array EUS. In this orientation the pulmonary artery (PA) and left atrium are superior. The image plane is rotated to bring the left atrium and pulmonary artery to the inferior side of the esophagus. The models are then shown again, and the plane is moved in the caudal and cephalad directions, much as during EUS.

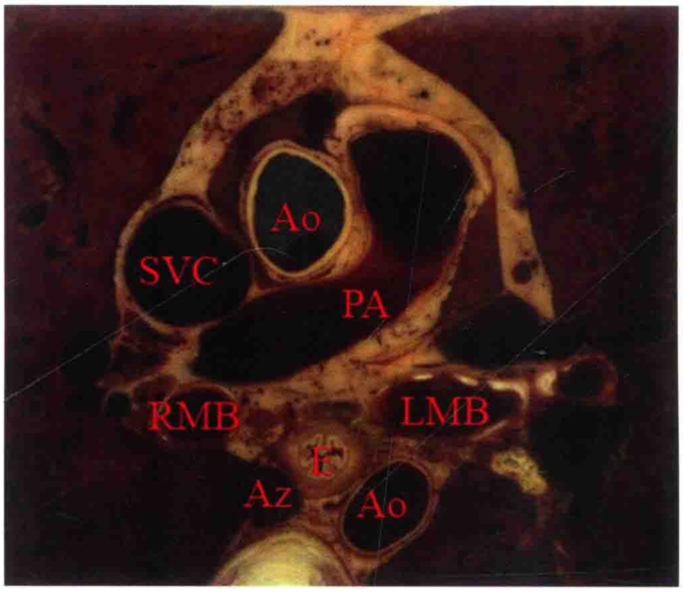

Figure 1.3 Transaxial cross-section of digital anatomy taken at the level of the subcarinal space (Ao = aorta [both ascending, superior in the image, and descending, inferior in the image, are shown]; Az = azygos vein; PA = pulmonary artery; RMB and LMB = right and left main stem bronchi; SVC = superior vena cava).

Normal EUS anatomy from the stomach

Radial array orientation (Video 1.3)

Endoscopic ultrasound of the stomach differs from EUS at other sites since the stomach does not constrain the endoscope tightly. It is important to follow anatomical structures (such as in a station approach) to avoid getting lost.

The video shows models of the stomach, esophagus, duodenum, gallbladder, pancreas (brown), the aorta, splenic artery, hepatic artery and left gastric artery (red), adrenal glands (pink), and splenic, superior mesenteric veins (dark blue) as viewed from behind. A plane is passed that is similar to the image plane generated during radial array EUS. The resultant cross-sectional anatomy starts at the level of the gastroesophageal junction, with the aorta and inferior vena cava (IVC) labeled. The aorta (which is collapsed) is followed, which brings the pancreas and left adrenal gland into view. The first artery that comes off the aorta in the abdomen is the celiac artery. There is a trifurcation into the splenic, hepatic, and left gastric arteries (LGA), although the LGA is generally smaller and difficult to see. It is shown in the video at the "x" just before the bifurcation into the celiac and hepatic arteries as identified.

The superior mesenteric artery (SMA) comes off the aorta just distal to the celiac artery. Various endoscope maneuvers can be used to bring the portal confluence into view, and then the splenic vein can be used as a guide to visualize the pancreas body, left adrenal, kidney, and spleen. The diaphragm can be easily imaged between the kidney and the vertebrae.

Linear array orientation (Video 1.4)

The linear array exam also follows the aorta to the stomach, but, as shown Video 1.4, the image plane across the pancreas is generally obtained through a sweeping motion. The first major gastric landmark is the origin of the celiac artery and SMA from the aorta (Figure 1.4). The superior mesenteric vein (SMV), portal vein, and splenic vein can be used as guides to go back and forth across the pancreas and in the process, the left adrenal, kidney, and spleen can be seen. The splenic artery runs roughly parallel to the splenic vein, but is generally tortuous.

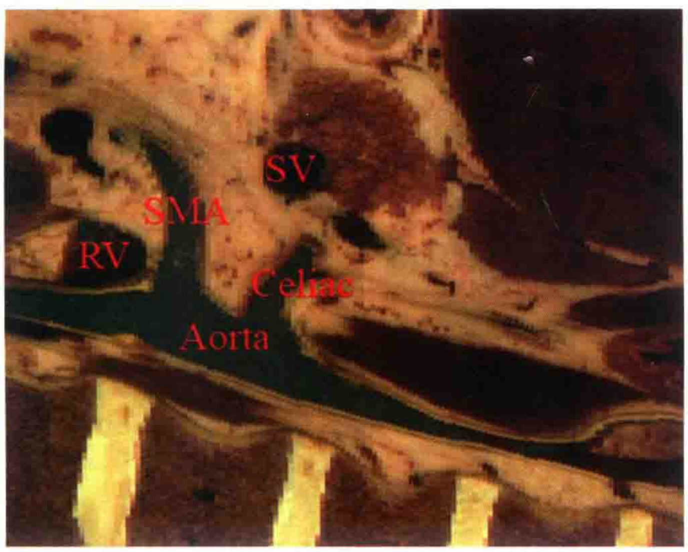

Figure 1.4 Sagital cross-section of digital anatomy at the level of the gastroesophageal junction, similar to a view seen during linear array endoscopic ultrasound (EUS). The celiac and superior mesenteric arteries (SMA) are shown at their insertion into the aorta. The renal vein (RV) is shown adjacent to the SMA and the splenic vein is shown adjacent to the pancreas.

Normal EUS anatomy from the duodenum

Radial array orientation (Video 1.5)

The radial array EUS examination through the duodenum follows a constrained path, but the endoscope can be rotated to put various structures into the inferior aspect of the image plane, as shown in the models of the duodenum, pancreas (brown), portal and superior mesenteric veins (blue), aorta (red), and SMA (silver). There are many structures of interest in a rather small area, and most of the images obtained are from the posterior view, with the liver to the right and the pancreas to the left of the image screen. After leaving the pylorus, the pancreas can be oriented with the tail pointed either to the left or inferiorly, and the splenic vein runs in the same direction as the pancreas. Going through the duodenal bulb, the gastroduodenal artery (GDA) often appears. Without Doppler, the GDA can be confused with the common bile duct (CBD) since these structures are nearly parallel in orientation and are very close to each other. As the apex of the duodenal bulb is reached, the image plane captures a longitudinal view of the CBD and the portal vein. As the descending duodenum is reached, the bile duct is seen in cross-section and the inferior vena cava (IVC) comes into view. As the third part of the duodenum is reached, the image plane rotates in such a way as to give a longitudinal cut through the IVC and then passes underneath the junction of the SMA with the aorta. Branches of the SMV can be found and the renal vein is visible in the "armpit" formed at the insertion of the SMA into the aorta. A special area is then highlighted in Video 1.5. Models show how the gastroduodenal artery and the hepatic artery (in red) relate to the CBD (in orange).

Figure 1.5 shows a model with an image plane and Figure 1.6 shows the resultant planar anatomy, which forms the stack sign – a phenomenon in which the portal vein, CBD, and main pancreatic duct are captured in the same field.

Linear array orientation (Video 1.6)

The linear array exam of the duodenum is an excellent way to see the CBD and pancreatic head. The anatomy is difficult to understand since the endoscope image is tipped into the C-sweep of the duodenum, and then the image plane is swept in various angles, resulting in a cross-sectioning of the CBD and pancreatic duct (PD). The image planes employed can be appreciated from observing the models in the video. The cross-sections obtained can be positioned to first give a

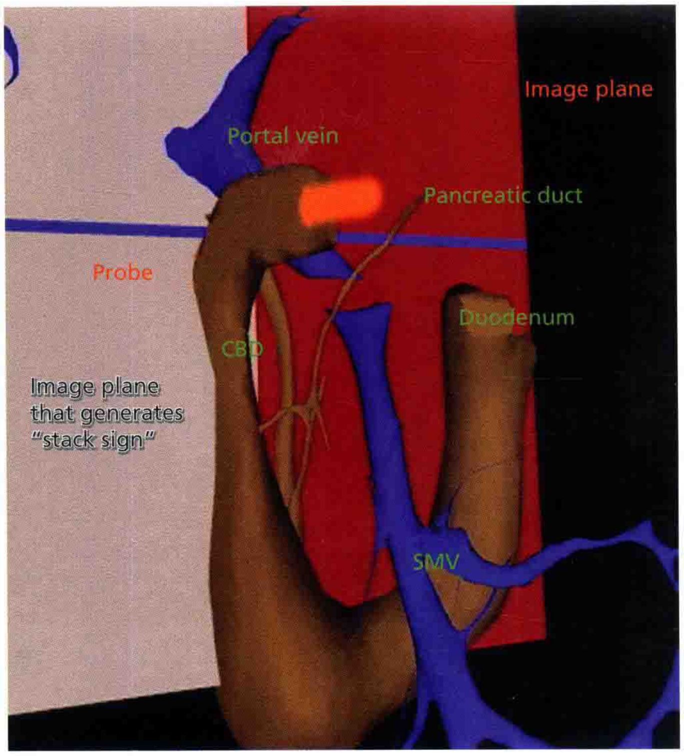

Figure 1.5 Visible Human Model of an image plane that is in the location in which radial array endoscopic ultrasound (EUS) generates the "stack sign", in which the portal vein, common bile duct (CBD), and pancreatic duct are in the same field. A probe in orange is shown going into the proximal duodenum. The superior mesenteric vein (SMV) is also shown.

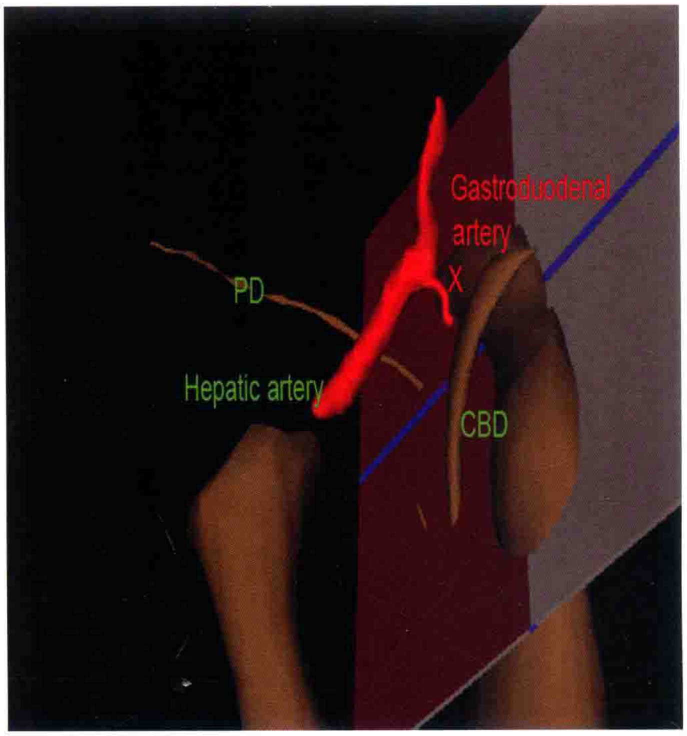

Figure 1.7 Visible Human Model with a plane that is in a location similar to what can be generated during linear array endoscopic ultrasound (EUS), showing the relative position of the gastroduodenal artery, pancreatic duct (PD), hepatic artery, and common bile duct (CBD).

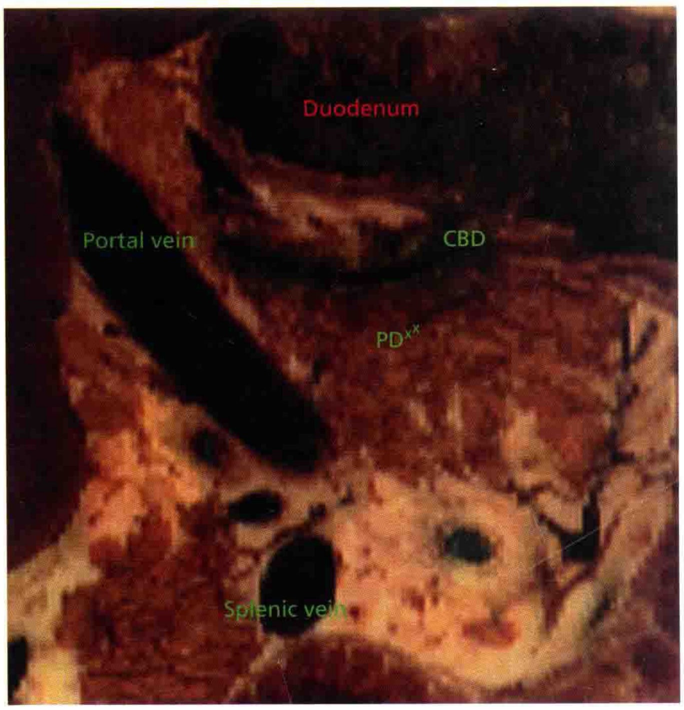

Figure 1.6 The cross-sectional anatomy within the plane shown in Figure 1.3. The common bile duct (CBD), pancreatic duct (PD), and portal vein are all in the same field ("stack sign").

longitudinal view of the CBD and both longitudinal views and cross-sections of the portal vein and SMV.

As seen in the first part of Video 1.6, if the endoscope is in the second part of the duodenum, the bile duct goes to the ampulla away from the transducer and the liver is towards the transducer. If the endoscope is in the duodenal bulb, as shown in the second part of the video, the liver is away from the transducer.

The GDA drapes over the portal vein and can be found most readily using Doppler. Figure 1.7 shows a model and Figure 1.8 the resultant cross-section where the GDA can be found.

Normal EUS anatomy from the rectum

Radial array orientation, male (Video 1.7)

Video 1.7 shows models of various male pelvic structures, starting with the rectum and sigmoid colon, the aorta, and the iliac arteries with internal and external branches. The SMA is included to show the anterior direction of the models. The prostate, bladder, coccyx, and sacrum are added sequentially. A second set of models is then shown which contains the rectum, sigmoid colon prostate, bladder, coccyx,