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Spiral CT aortography: an efficient technique for the diagnosis of traumatic aortic injury

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Abstract. The objective of this study was to assess the efficiency of spiral CT (SCT) aortography for diagnosing acute aortic lesions in blunt thoracic trauma patients. Between October 1992 and June 1997, 487 SCT scans of the chest were performed on blunt thoracic trauma patients. To assess aortic injury, the following SCT criteria were considered: hemomediastinum, peri-aortic hematoma, irregular aspect of the aortic wall, aortic pseudodiverticulum, intimal flap and traumatic dissection. Aortic injury was diagnosed on 14 SCT examinations (2.9 %), five of the patients having had an additional digital aortography that confirmed the aortic trauma. Twelve subjects underwent surgical repair of the thoracic aorta, which in all but one case confirmed the aortic injury. Two patients died before surgery from severe brain lesions. The aortic blunt lesions were confirmed at autopsy. According to the follow-up of the other 473 patients, we are aware of no false-negative SCT examination. Our limited series shows a sensitivity of 100 % and specificity of 99.8 % of SCT aortography in the diagnosis of aortic injury. It is concluded that SCT aortagraphy is an accurate diagnostic method for the assessment of aortic injury in blunt thoracic trauma patients.

Key words: Thoracic aorta – Trauma – Aorta rupture – Spiral CT – Angiography

Introduction

Aortic injury in blunt thoracic trauma has a very dismal prognosis. It occurs most frequently during motor vehicle accidents with high-speed deceleration or chest compression. It is responsible for about 16 % of immediate deaths and 85–90 % of patients with aortic injury will die prior to admission [1, 2]. Survivors have an increased mortality rate of 1–2 % per hour after the onset and only 2 % of untreated patients will survive beyond 4 months [1, 2]. Aortography, until recently, was considered as the gold standard, but some authors have suggested the use of spiral CT (SCT), not only as a screening modality but also as a diagnostic tool [3, 4]. SCT criteria for the assessment of aortic trauma relate to a hemomediastinum, a peri-aortic hematoma, an aortic pseudodiverticulum, an irregular wall or a fuzzy contour of the opacified thoracic aorta, and an intimal flap with or without a traumatic dissection. This report deals with 11 surgically proven and two necropsy proven traumatic aortic injuries among 14 patients, in whom the diagnosis of aortic injury was established by SCT aortography and confirmed by digital angiography in five cases. The first five cases in this series have been published previously [5].

Subjects and methods

Between October 1992 and June 1997, all patients admitted for blunt thoracic trauma had a chest radiograph that was initially interpreted by a senior resident or a staff member. One of our SCT units is located next to the emergency room, allowing physicians in the acute section to obtain prompt and easy access to our SCT. Since October 1992 we have used this SCT unit as a screening modality for aortic injury in blunt trauma patients. On the basis of the severity of the trauma, the associated traumatic lesions and the chest plain film findings, 487 SCT examinations of the thorax were done, among which 14 traumatic aortic injuries (2.9 %) were identified in 12 men and 2 women, aged 20–76 years. Nine subjects were involved in a high-speed deceleration motor vehicle accident, four fell from a height of 3–8 m and one had his chest crushed by a block of concrete.

All 487 patients were examined with a SCT unit (General Electric HiSpeed Advantage). Six patients

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had an initial chest survey without intravenous contrast medium injection, which was followed by an injected SCT series. The other eight patients underwent an immediate intravenous contrast-enhanced series. Non-enhanced SCT examinations were carried out at 120 kV, 200 mA with a X-ray beam collimation of 7 mm, a pitch of 1.5:1 and a section reconstruction interval of 5 mm (7/1.5:1/5). Enhanced SCT examinations were performed 20 s after the beginning of intravenous injection of a maximum of 200 ml of nonionic contrast material at a concentration of 150 mg iodine/ml at a rate of 5 ml/s. Scan parameters were 3/1.5:1/1.5. Images were obtained from 2–3 cm above the aortic arch down to the diaphragm during quiet breathing, with a field of view of 26 cm.

Two-dimensional (2D) reformatted coronal or sagittal oblique images were obtained. Three-dimensional (3D) reconstructions, in surface-shaded display (SSD) and maximum intensity projection (MIP) algorithms, were also performed.

Five of the first eight patients had digital angiography of the thoracic aorta, through a femoral approach, using a 6 Fr pigtail catheter positioned 2 cm above the aortic valve. At least two views were obtained: one anteroposterior and one left anterior oblique. Forty to fifty milliliters per series of a nonionic solution of 300 mg iodine/ml at a flow rate of 20 ml/s was injected. All subjects underwent surgical thoracic exploration.

All SCT examinations of the chest and all SCT aortography of the blunt thoracic trauma patients were reviewed. Three radiologists assessed all SCT aortography for the presence of a hemomediastinum and a peri-aortic hematoma, a traumatic pseudodiverticulum, an irregular aspect of the contour or the wall of the thoracic aorta, an intimal flap and a traumatic dissection. All five digital aortographies were also analyzed by the same radiologists, who looked for a traumatic pseudodiverticulum, an irregular aspect of the aorta at the level of the isthmus and filling defects or leakage of contrast.

Results

At admission, all 14 emergeny chest plain films displayed an enlarged mediastinum, a blurring of the aortic knob in all but three patients, a depressed left main bronchus in ten subjects and a trachea displaced to the right in nine patients. Eight patients had bilateral pleural effusion or hemothorax, one had the right shoulder and the two first right ribs broken and one had multiple rib fractures on the right side. One trauma patient had an associated ruptured left diaphragm.

SCT examinations were all easily achieved and all but two were of excellent quality, even with superficial breathing in 11 cases. Two SCT examinations displayed streak artifacts over the mediastinum, related to trauma lesions of the upper limbs that did not allow them to be maintained in an upward position. Nevertheless, in one of these two cases the aortic injury was correctly diagnosed and located. All SCT demonstrated a hemomediastinum.

Fig. 1. A 35-year-old man involved in a building-site accident. A 3-mm SCT section obtained during intravenous injection of 180 ml of iodinated contrast at a concentration of 150 mg/ml and a flow-rate of 5 mm/s. Close-up view shows a diffuse hemomediastinum related to the usual patterns of an aortic lesion involving the isthmus level: a pseudodiverticulum *(arrow)* and an intimal flap *(open arrow)*

Aortic injuries were first identified on axial images as a pseudodiverticulum of the proximal descending thoracic aorta in 11 cases, usually associated with an intimal flap (Fig. 1). Among them, eight SCT examinations diagnosed a typically anterior injury of the descending aorta, at the level of the isthmus, associated with a peri-aortic hematoma. Two other patients had a double aortic injury – the proximal one being located posteriorly and the distal one anteriorly – that was particularly well displayed by 2D sagittal oblique reformatted images and 3D reconstructions (Fig. 2). The last patient had a wide injury extended from the aortic arch convexity down to the level of the isthmus.

One SCT examination showed an intramural hematoma of the descending aorta from the distal arch down to the diaphragm, associated with a hemomediastinum, multiple rib fractures and an obvious ruptured left diaphragm. No typical traumatic pseudodiverticulum was depicted. At surgery, no classical isthmic trauma was found and exploration of the descending aorta revealed an aortic injury at the level of the thoraco-abdominal junction. Retrospectively, axial sections at that level demonstrated an irregular and fuzzy aortic lumen of the distal thoracic aorta, at the level of the left diaphragmatic rupture, with chest herniation of the colon and the stomach.

In one patient, the aortic trauma was located at the convexity of the aortic arch. Because of an unexpected anatomic variation, the injury was difficult to diagnose directly from the axial CT sections. Indeed, the left vertebral artery originated from the aortic arch between the origin of the left common carotid and left subclavian arteries. The tear was located immediately after the origin of the left subclavian artery and, therefore, on contrast-enhanced axial CT sections, five high-density areas appeared above the aortic arch corresponding to the

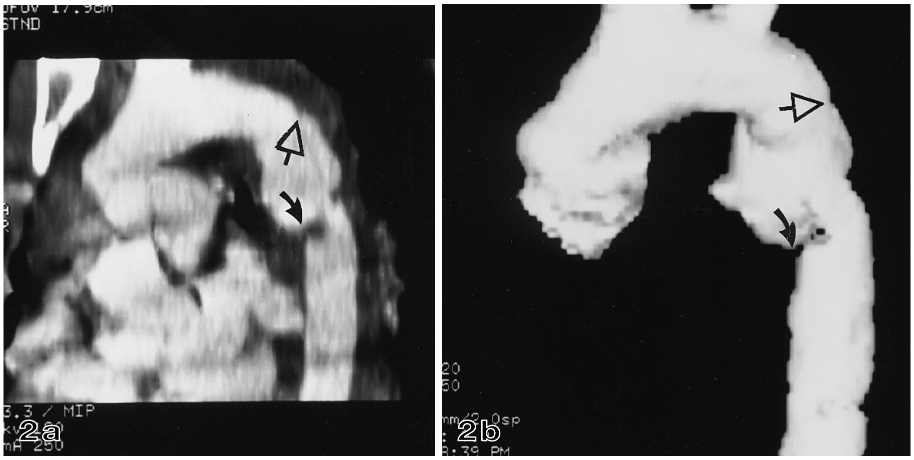

Fig. 2 a, b. A 23-year-old woman involved in a high-speed deceleration accident, as a rear passenger on a motorcycle. **a** Two-dimensional sagittal oblique reformatted image and **b** 3D surface reconstruction both clearly depict two sites of aortic lesion: a posterior one involving the isthmus *(open arrow)* and, 2.5 cm more distally, an anterior one involving the proximal descending aorta *(arrow)*

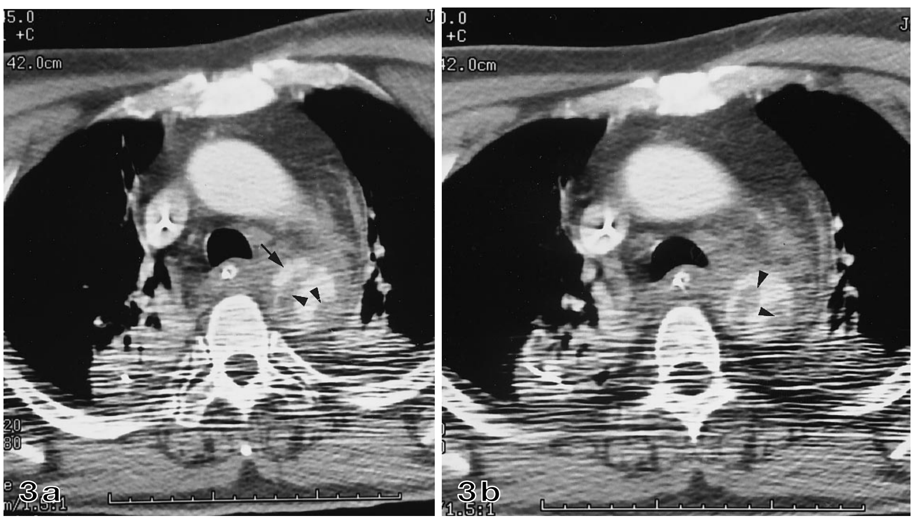

Fig. 3 a, b. A 64-year-old man involved in a high-speed crash. **a, b** SCT sections obtained at 5-mm intervals reveal a large hemomediastinum involving the isthmus area, and an incomplete irregular aortic lumen with an anterior pseudodiverticulum *(arrow)* and two unusual luminal filling defects *(arrowheads)*. Despite major streak artifacts, the diagnosis of aortic lesion was assessed by SCT only. At surgery, the filling defects were found to represent bulging mediastinal fat within the aortic lumen

origin of the four aortic arch vessels and to the tear. In this particular case, the 3D MIP and SSD reformatted images were helpful in diagnosing the tear and determining the location of the injury.

Finally, one SCT examination revealed, in spite of mediastinal artifacts, a hemomediastinum and low-attenuation filling defects within the lumen of the descending aorta, without peri-aortic hematoma and traumatic pseudodiverticulum, corresponding at surgery to mediastinal fat tissue bulging into the lumen of the injured aorta (Fig. 3).

In five patients, digital aortography was performed. An irregular aspect of the proximal descending aorta was demonstrated at the level of the isthmus in four cases, associated with a traumatic pseudodiverticulum in three patients. In one patient, direct visualization of the contrast leak was shown at the level of the isthmus. The tear of the convexity of the aortic arch was also depicted by angiography, as well as the anatomic anomaly. On one angiogram a very thin regular filling defect 8 cm long was also visible along the medial wall of the descending aorta, with no evidence of isthmic pseudodiverticulum. According to SCT sections, this filling defect corresponded to a traumatic dissection associated with an aortic intramural wall hematoma (Fig. 4), confirmed later by transesophageal echography (TEE) and surgery. Furthermore, both SCT and TEE displayed in this patient an intimal flap at the isthmic level that could not be identified on the three different views of the corresponding aortography.

Ten patients underwent immediate surgery. One subject was operated on 2 days after the diagnostic SCT because of severe associated brain and pelvic traumatic lesions. Another one underwent surgery 48 h after the trauma, due to the fact that her chest radiograph was presented late to the radiologist. The enlarged mediastinum thus remained undetected for 48 h. SCT aortography demonstrated a typical isthmic aortic injury, associated with a hemomediastinum. The patient was immediately sent to the operating room for surgical repair. Two patients did not survive their severe brain damage and did not undergo a thoracotomy. The aortic lesions were confirmed at necropsy.

Surgery confirmed all but one diagnosis determined by SCT and angiography. The SCT and angiogram false-positive examinations corresponded to a wide insertion of the ductus arteriosus. According to the surgeons, the descriptions of the location and the extent of the true positive injured aorta afforded by SCT sections were very accurate.

According to the radiological and clinical follow-up of the other 473 patients, we are aware of no false-nega-

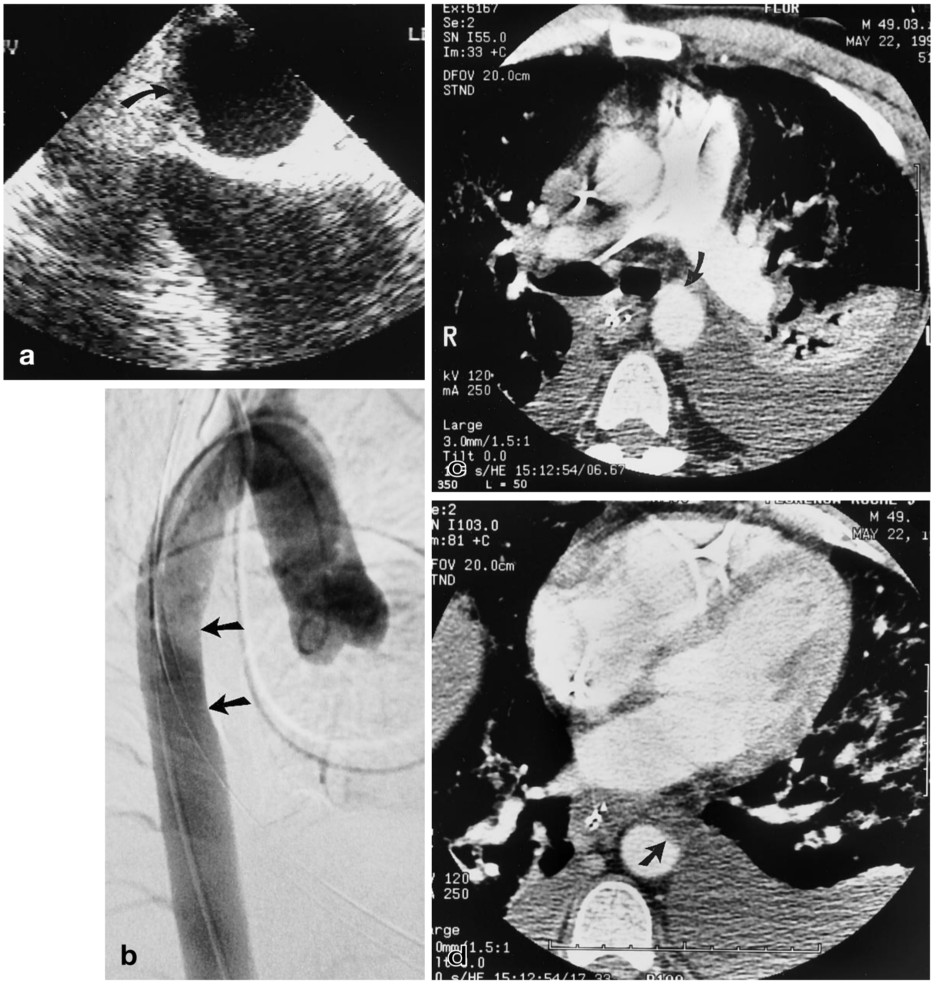

Fig. 4 a–e. A 47-year-old motor vehicle driver involved in a high-speed accident while wearing a seat-belt. A conventional 7/1.5:1/5 mm SCT acquisition displayed a large hemomediastinum but failed to demonstrate an unequivocal lesion. **a** Transesophageal echography (TEE) examination obtained immediately after the inconclusive SCT showed an anterior intramural hematoma *(arrow)* involving the descending aorta. The location of the aortic injury was not demonstrated by TEE. **b** Digitized aortogram with three views showed the extent of the intramural hematoma involving the descending aorta *(arrows)* but no definite aortic trauma. **c** A second SCT obtained 12 h later with adequate parameters (3/1.5:1/5) displayed an anterior isthmic pseudodiverticulum *(arrow)* and a barely visible intimal flap. **d** SCT section obtained more caudally shows the anterior intramural hematoma *(arrow)*. **e** A second TEE obtained immediately before surgery is now able to display a floating intimal flap, at the precise site of the aortic lesion

tive SCT examinations. Among the 487 SCT examinations of the chest for blunt thoracic trauma, we diagnosed 14 aortic injuries that were surgically or pathologically proven in 13 cases. According to our SCT aortography criteria, our results show a sensitivity of 100 % and a specificity of 99.8 % for the detection and diagnosis of blunt aortic injury.

Discussion

Aortic injury in thoracic blunt trauma patients generally has a fatal outcome. Theories have been proposed to try to explain the mechanism of aortic trauma during a high-speed deceleration motor vehicle accident [1, 6–9] or chest compression. Eckert [6] estimates that a frontal crash of a vehicle at 80 km/h induces a deceleration force of about 85 g. But mechanical-etiologic studies demonstrated that during deceleration the forces encountered in a motor vehicle accident are not sufficient to rupture an aortic wall [1, 7]. Therefore, other possible mechanisms, such as the ‘osseous pinch’ [8, 9] have been proposed to explain the aortic injury. However, whatever the mechanism, one tends to consider only that aortic injury has a very dismal prognosis and therefore urges a prompt and precise diagnostic modality to carry out adequate and immediate surgical treatment on patients who have survived until admission.

Plain film of the chest obtained in the emergency unit was shown to be of limited value [2, 3, 10]. Nevertheless, frontal chest radiographs have a 98 % negative predictive value when findings are unequivocally normal [2, 3, 10]. Frequently supine chest films of blunt trauma patients present a widened mediastinum induced by the patient position or due to normal mediastinal fat or to overdistention of the superior vena cava by a large amount of fluid perfusion. According to Sandor [11], hemomediastinum arises from small venous tears, vertebral or rib fractures in 87.5 % of cases. Indirect signs of aortic trauma with hemomediastinum and peri-aortic hematoma, such as a right displaced trachea, a depressed left bronchus, a blurring of the aortic knob, or fracture of the first ribs on the chest plain film have poor predictive value [2, 3, 10]. In our series, every patient had two to four indirect signs of aortic trauma on the chest plain film obtained at admission. Until recently, aortography – and mainly digital aortography, with a sensitivity and specificity of 98 % [12] – was considered the gold standard modality. Less invasive procedures such as CT and SCT aortography are now considered efficient examination tools of the thoracic aorta [3, 4, 13]. SCT is known to demonstrate mediastinal hematoma accurately. Several studies have shown that a normal mediastinum on conventional CT has a high negative predictive value for aortic trauma of 99.3 % [3, 4, 10, 14]. Mirvis [15] recently reported a 99.9 % negative predictive value of aortic injury if the mediastinum is normal on SCT examination. Therefore SCT is now used as a screening modality in many trauma centers, decreasing the number of unnecessary aortographies and their related costs.

One of our SCT units is located next to the emergency room and partially dedicated to the acute section. Access from the emergency room to this SCT unit is quick and easy. This allows our physicians to obtain any examination rapidly and especially to screen thoracic aortic injury in blunt trauma. Our ratio of 14 SCT positive examinations in 487 patients is only 2.9 %, but corresponds to the findings in other published series.

Our SCT series is the second largest one published [16] and the largest in Europe. It shows that SCT aortography allowed a prompt and precise diagnosis in 13 of 14 cases. All patients had an unequivocal mediastinal hematoma and all but two cases, among which was the false-positive subject, had a peri-aortic hematoma. The traumatic pseudodiverticulum at the level of the isthmus was well shown. The diagnosis of aortic injury was performed on the axial sections in all but one particular tear of the convexity of the aortic arch. Axial sections are very accurate for the demonstration of the traumatic pseudodiverticulum and the intimal flap. Intimal flaps showed on axial SCT sections allowed the epicenter of the aortic injury to be located and are sometimes difficult to display by aortography. An extension of the injury, such as a traumatic dissection or an intramural hematoma, is also very easily displayed by SCT axial images, or by TEE, as was the case in one of our patients. Reformatted 2D images in our series demonstrated the two double rupture cases. Reformatted 3D SSD images of the classic isthmic injuries were mainly useful for convincing the thoracic surgeons who were not familiar with the SCT aortography technique. After the first eight cases, patients were immediately referred to the surgeons on the basis of the SCT aortography results without performing a digital aortogram.

In our series of 14 patients there was one false-positive result which showed at angiography a small outpouching at the level of the isthmus. The corresponding SCT was markedly spoiled by streak artifacts over the mediastinum due to the large size of the patient and the position of a fractured right upper limb. An irregularity of the medial aspect of the proximal descending aorta associated with a small pseudodiverticulum was demonstrated by SCT sections and 2D reformatted images. This false-positive examination corresponded at surgery to a wide insertion of the ductus arteriosus.

In 80 % of cases aortic lesions in surviving patients occur at the level of the isthmus [17]. But in 3 % of the patients the aortic trauma occurred at the thoraco-abdominal level. Among our 13 true-positive patients, such a location was encountered once. This suggests we should consider it mandatory to obtain an SCT examination of the entire thoracic aorta.

Our data are very similar to those of Gavant et al. [16], who in 22 months screened 3229 patients with blunt chest trauma and found 38 thoracic aorta and great vessels injuries. Twenty-eight injuries were located at the level of the descending aorta and nine at the level of ascending aorta; there was also one false-positive examination with both angiography and SCT examinations. They had no false-negative SCT examinations according to the follow-up of patients. SCT was better than angiography in the description of the extent of the trauma. According to our experience and the literature, SCT aortography seems to have the same pitfalls as angiography in cases of aortic trauma.

SCT aortography is fast and easy to perform at any time. In most institutions, angiographic teams are on call at night or during weekends and a 45–60 min delay is usually required for them to reach the hospital and prepare the patient for angiographic examination. This is longer than the time required for a resident in house to perform a SCT aortography, even if associated 3D reformatted images are needed. SCT can also combine examinations of other anatomic areas, which can be of major importance in resuscitating trauma patients. These additional examinations can be performed either before (for the brain) or after (for the abdomen) the SCT aortography of the thoracic aorta. SCT aortography that shows an unequivocally normal mediastinum, no periaortic hematoma and a regular aorta surrounded by normal fat, excludes an aortic injury in cases of blunt thoracic trauma.

Digital aortography still has a major advantage over SCT as regards depiction of aortic arch vessels lesions. These occurred in 1.6 % of cases in Mirvis et al.'s series and the axial transverse orientation of subclavian arteries does not favor their evaluation by SCT.

In conclusion, according to the results of our series, as well as finding a SCT sensitivity of 100 % and specificity of 99.8 %, which are similar to those of other series [13, 15, 16], we consider that SCT aortography is the examination of choice and that it should be performed prior to digital angiograms to reduce the number of unnecessary and expensive angiographic examinations. SCT has to be performed to assess an aortic injury in the blunt thoracic trauma patient and should replace aortography in almost all cases.

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Book review

European Radiology

Hiss, S.S.: Introduction to Health Care Delivery and Radiology Administration. Philadelphia: W.B.Saunders, 1996. 275 pp., (ISBN 0-7216-5314-6), £ 17.95.

This is a textbook mainly for educational purposes. Its title comprises health care delivery and radiology administration but its emphasis is on health care (six of ten chapters). It may be said right from the start that the link between the two topics is somewhat weak.

The first chapter is a historical review of US health care delivery and gives the background for today's organization, administration and financing of US health care, which is dealt with in detail in Chapter 2. Chapters 3 and 4 deal with the hospital as an organized and integrated system and financial aspects of hospital management, respectively. Chapter 5 deals with the health care insurance system in the USA. These five chapters are very much centered on US conditions, but valuable information can be found for non-US readers. The sixth chapter on quality care is useful for any quality-conscious reader.

Chapter 7, 8 and 9 are on radiology management, logistics and intradepartmental dependencies and on radiology services provided by free-standing facilities. Much is mainly of interest to US readers but a good proportion of the material is general and of interest to any reader.

Each chapter starts with 'objectives for study' and ends with 'study questions'. The language is easy to follow; tables and charts are excellent. The index is adequate. There are no references for further reading.

The first six chapters could be a general introduction to health care delivery in the USA and the radiology part could be a separate book, also mainly for a US public.

Despite the book's several advantages it is not recommended for a European public. J. H. Göthlin, Göteborg