Computed tomography in diagnosis of abdominal masses in infancy and childhood

Comparison with excretory urography

JOHN C. LEONIDAS, BARBARA L. CARTER, LUCIAN L. LEAPE, MAX L. RAMENOFSKY, AND ALAN M. SCHWARTZ

From the Department of Radiology (Division of Pediatric Radiology), and Department of Surgery (Division of Pediatric Surgery), New England Medical Center and Tufts University School of Medicine, Boston, Massachusetts

SUMMARY Computed tomography (CT) of the abdomen and pelvis was performed in 26 instances of suspected mass in 24 infants and children. The information obtained was compared to that of standard abdominal radiography and excretory urography (IVP). Results were analysed prospectively. CT was able to detect and define masses more precisely than abdominal radiography and IVP. The information obtained by CT, in a single noninvasive examination emitting minimal ionising radiation, seems comparable to that offered by a combination of multiple radiological and other imaging procedures. It is conceivable that with accumulating experience and further technological improvement CT may become an excellent screening procedure in the investigation of abdominal and pelvic masses. The high cost of CT scanning may be offset by the benefits cited.

Computed tomography (CT) was developed by Hounsfield of EMI-tronics Inc., Central Research Laboratories in 1972 and within a short time practically revolutionised imaging of the skull and its contents (Hounsfield, 1973; Ambrose, 1973; Baker *et al.*, 1974; New *et al.*, 1974; Baker, 1975). CT scanning is a noninvasive and easily reproducible diagnostic procedure carrying virtually no risk to the patient, other than minimal radiation exposure equivalent to conventional radiological examinations (American Academy of Pediatrics, 1977; Brasch *et al.*, 1977). It is not surprising therefore that CT scanning has had a profound impact on the practice of neurology, neurosurgery, and neuroradiology, having reduced sharply the need for more conventional diagnostic procedures, such as A-mode echoencephalography, intracranial pneumography, and radionuclide brain scanning (Baker, 1975).

Several reports indicate the usefulness of body CT scanning in adults (Alfidi *et al.*, 1975; Sheedy *et al.*, 1976; Carter *et al.*, 1977), and in infants and children experience with CT of the head, neck, and spine is rapidly growing (Harwood-Nash and Breckbill, 1976; Hammerschlag *et al.*, 1976). Experience with body CT in paediatric patients, however, is scant (Boldt and Reilly, 1977; Pinto and Becker, 1977), and

no attempt has been made to evaluate its performance in comparison with other radiographic techniques. Excretory urography (intravenous pyelography, IVP) has proved reliable in the diagnosis of abdominal and pelvic masses in infants and children and is usually the first radiological examination to be performed. A comparison was therefore made between CT scanning of the abdomen and pelvis and IVP, in a group of infants and children known or suspected of having abdominal and/or pelvic masses.

Materials and methods

Since July 1975, when a body scanner was installed at the Tufts-New England Medical Center, a total of 26 CT scans of the abdomen and pelvis were performed in 24 infants and children. In all patients the purpose of the examination was clinical suspicion of a mass. There were 16 males and 8 female patients, ranging in age from 1 day to 14 years. They had had the usual laboratory investigations and in addition plain film radiography and IVP before CT scanning. Other imaging examinations were only performed as indicated in the individual patient. Moreover CT studies were limited to only those patients who still presented important diagnostic problems after other imaging examinations had been completed.

Received 21 June 1977

All CT scans were performed with an Ohio Nuclear Delta scanner which produces two simultaneous 13 mm sections in 2.5 minutes. The unit provides images in a 256×256 matrix. X-ray absorption values are recorded from low absorption values of -1000 (air) to high absorption of $+1000$ (dense bone). The absorption of water is 0. Detailed description of the principles and technique of CT scanning is given elsewhere (New *et al.*, 1974; Harwood-Nash and Breckbill, 1976).

General anaesthesia was not used since sedation with chloral hydrate (50 mg/kg to a maximum of 100 mg/kg) proved adequate. In one newborn and all children older than 6 years no sedation was used. Each procedure was monitored by a radiologist who determined the necessity for additional views or sections or injection of contrast medium.

IVPs were obtained before CT scans. After an initial abdominal radiography, sodium diatrizoate 50% was injected intravenously (2–4 ml/kg of body weight) and films were taken at 3 and 5 minutes. Subsequent films were obtained as required for complete demonstration of the urinary tract. The diagnostic contribution of CT was determined before surgical confirmation or final diagnosis and compared with that of the IVP. Data were collected prospectively.

Certain limitations leading to biased conclusions should be noted. (1) Many abdominal masses proved to be outside the retroperitoneal space and less likely to have produced abnormalities on the IVP. Since the IVP is the initial evaluation of a child suspected of having an abdominal mass, we considered the comparison valid. (2) The results of the IVP were available during the interpretation of CT. (3) Experience with CT was limited, especially during the early period of the study. With additional experience the accuracy of interpretation of CT scans increased. (4) Motion artefacts on CT scans caused degradation of the image in some instances. Greater application of CT to paediatrics is expected with the latest generations of CT scanners now available, with scan times of 2–5 seconds. Although motion artefacts may still be present, they will be sharply reduced. (5) Intravenous and oral contrast material for scanning was used sparingly in our patients, a fact which has undoubtedly limited information.

To facilitate comparison of data between IVP and CT scanning an arbitrary scoring system was devised. A normal study was given a score of 0. If both studies were positive and provided similar information, each was given a score of 1. If either study was the only one positive, or it offered additional information not obtained from the other, it was given a score of 2. False-positive results were given a negative value (-1 or -2 depending on

whether the other examination was also misleading). False-negatives were assigned 0. The presence of a mass and its anatomical position and size was confirmed in the majority of cases by surgical exploration, and its nature by histological examination. In some instances exploration was carried out only to confirm absence of disease. In a few cases strong clinical evidence (i.e. known primary neoplastic disease) supported by positive findings on a number of imaging procedures indicated the presence and extent of tumour. Absence of disease was most often established by lack of any abnormalities on a variety of diagnostic tests and imaging examinations, disappearance of symptoms and signs, and no evidence of abnormality on follow up.

Results

Table 1 summarises the abdominal and pelvic masses found. Comparison of the diagnostic performance of IVP and CT is given in Table 2. 2 patients had IVPs and CT scans twice.

Table 1 Final diagnosis in 24 patients

Neural crest tumour	6
Rhabdomyosarcoma	3
Retroperitoneal lymphangioma	2
Wilms's tumour	2
Ovarian dermoid	1
Ureteropelvic junction obstruction	1
Choledochal cyst	1
Hydrops of the gallbladder	1
Retroperitoneal haematoma	1
Normal	6
Total	24

CT scanning and IVP showed similar information in 12 instances. In 3 cases of neural crest tumour CT gave superior information (better definition of intraspinal extension of tumour in 1, calcification enhancing the diagnostic probability of neuroblastoma in a second (Fig. 1), and correct localisation of tumour in the presacral space in a third). In one case of rhabdomyosarcoma soft tissue tumours were shown by CT but not by IVP. One Wilms's tumour arising from the anterior surface of the kidney gave the impression of an extrarenal mass on IVP, but it was correctly defined as an intrarenal tumour by CT. Ultrasound, however, also gave correct information in this case. Diseases of the liver and gallbladder were better defined by CT (Cases 13, 17, 18, Figs. 2, 3), as expected by their nature. The only possible false-positive information obtained by CT was in Case 24, a 13-year-old girl who complained of persistent abdominal pain after trauma. A very small mass was detected by CT anterior to the liver, unconfirmed by any other test, but she soon became

Table 2 Comparison of findings between IVP and CT

Case no.	Sex	Age	Clinical findings	Abdominal x-ray and IVP	CT	Final diagnosis	Comments
1	F	4½ yr	Abdominal mass	1	2	Retroperitoneal ganglioneuroblastoma with intraspinal component	Extent of tumour more accurately defined by CT; extradural extension best defined by myelography
2	M	7 m	„	1	1	Retroperitoneal neuroblastoma	
3	M	1 yr	Urinary retention; constipation	1	2	Presacral neuroblastoma	IVP suggested intravesical tumour
4	M	2 yr	Abdominal mass	1	2	Retroperitoneal neuroblastoma	Calcification detected by CT only
5	M	10 d	„	1	1	Retroperitoneal neuroblastoma	
6	F	4 m	„	1	1	Adrenal neuroblastoma (cystic)	Cystic mass identified by IVP and CT; neuroblastoma detected microscopically on wall of adrenal cyst
		6 m	Persistently raised VMA postoperatively	0*	0*	Neuroblastoma in para-aortic node; liver metastases	Liver metastases 1-3 mm in diameter
7	F	2 yr	Abdominal mass	1	1	Rhabdomyosarcoma of bladder and peritoneum	
8	M	7 yr	Abdominal pain and neurological deficit	0*	1	Recurrent pelvic rhabdomyosarcoma	
9	F	14 yr	Mass in groin	1	2	Extensive pelvic and abdominal rhabdomyosarcoma	Ureteric obstruction by tumour with hydronephrosis on IVP and CT; multiple intra-abdominal metastatic foci best defined by CT
10	M	3 m	Abdominal mass	1	1	Retroperitoneal lymphangioma	
11	M	5 m	„	1	1	Retroperitoneal lymphangioma	
12	M	3 yr	„	1	1	Wilms's tumour	
13	M	7 m	„	1	2	Wilms's tumour	Intrarenal origin of tumour best defined by CT
		2 yr	Epigastric mass	1	2	Radiation atrophy of R lobe of liver with compensatory hypertrophy of L lobe	Identification of nature of mass by CT averted operation
14	F	2½ yr	Abdominal mass	1	1	Ovarian dermoid	
15	M	1 d	„	2	1	Hydronephrosis caused by ureteropelvic junction obstruction	
16	M	11 yr	Haemophilia; flank pain	1	1	Retroperitoneal haematoma	
17	M	4 yr	Abdominal pain; vomiting	0*	1	Choledochal cyst	Cyst shown equally well by ultrasound
18	M	13 yr	Aplastic anaemia, abdominal pain, fever	0*	1	Hydrops of gallbladder	Oral cholecystography informative
19	F	12 yr	Persistent abdominal pain	-1	0	No evidence of disease	IVP false positive, suggesting pelvic mass; CT indicated ureteral displacement by psoas muscle
20	F	4 m	Twin of patient with neuroblastoma	0	0	No evidence of disease	
21	M	7 yr	Abdominal pain; anaemia; neoplastic cells in bone marrow	0	0	Leukaemia	
22	M	2 yr	Persistent diarrhoea; raised VMA on one occasion	-1	0	No evidence of disease	IVP questionably positive for adrenal mass
23	M	5 w	Questionable abdominal mass	0	0	No evidence of disease	Negative exploratory laparotomy
24	F	13 yr	Abdominal pain after trauma	0	1	Indeterminate; now well	Small mass anterior to liver shown on CT may have represented haematoma

0 = negative test; 0* = false negative; -1 = false positive. For explanation of other numbers, see text. VMA = vanillylmandelic acid.

asymptomatic. The finding on CT may have represented a small haematoma.

IVP was superior to CT only in a case of right congenital hydronephrosis, better defining the ureteropelvic junction obstruction as a cause. There

were two false-positive examinations by IVP (Cases 19, 22). In both, correct information from CT scanning avoided abdominal exploration for these normal children. In addition, the nature of the mass in Case 13 proved on CT not to be a metastasis

(a)

(b)

Fig. 1 Case 4. (a) CT scan with contrast enhancement at the level of the kidneys shows lateral displacement of both the right (RK) and left kidney (LK) by a large mass anterior to the spine. Arrows indicate calcifications within the mass; v = vertebra. (b) IVP shows the mass but there are no detectable calcifications. Lymph node enlargement was therefore considered in the differential diagnosis. At operation a large neuroblastoma was found.

Fig. 2 Case 13. Postoperative CT scan 17 months after right nephrectomy for Wilms's tumour. Palpable epigastric mass, seen also on IVP. CT scan shows atrophy of the right lobe of the liver (RL) secondary to radiation injury, and compensatory hypertrophy of the left lobe (LL). v = vertebra, LK = left kidney (contrast is seen within its collecting system), ri = rib; S = spleen; gb = gallbladder. Black areas represent air within the bowel.

Fig. 3 Case 17. Choledochal cyst (CC) and dilated intrahepatic bile ducts (ihd). There was no palpable mass on examination and there was no evidence of jaundice at this time. RLL = right hepatic lobe; LLL = left hepatic lobe, S = spleen; v = vertebra.

obviating the need for laparoscopy. The overall performance of CT scanning was superior, with a score of 26 versus 15 for the IVP.

Discussion

The data obtained from this small group of infants and children suggest that CT scanning of the abdomen and pelvis is capable of accurately localising masses and in many instances of providing anatomical information not available by conventional abdominal radiography and IVP. It is perhaps unfair to compare CT and IVP on a one-to-one basis, since most of the information expected from the latter is limited to the urinary tract and retroperitoneal space. This limitation in itself, however, emphasises the value of CT which is capable of studying all intra-abdominal structures and tissues in one examination. Many times the localisation of a mass (whether intraperitoneal or retroperitoneal) is not clinically obvious, and investigation starts with an IVP, pursued if necessary with upper gastrointestinal contrast study, barium enema, gallbladder series, abdominal echography, and some times even arteriography. When the information of all such imaging methods is combined it probably matches that obtained from CT scanning, but at the expense of time, higher radiation exposure, and often the risk of morbidity related to invasive procedures such as arteriography. At the present time CT scanning is expensive (\$195 without and \$245 with contrast enhancement at this institution, compared to \$122 for an IVP). This disadvantage is offset by significantly improving the quality of patient care as more invasive examinations are avoided and the danger of unnecessary operations is minimised. It is possible that overall cost may actually decrease with the use of CT because of the need for fewer diagnostic tests, shorter hospitalisation, and restriction of surgery, though a definite statement will have to await further studies. It is hoped that with increasing experience and improvement in technology CT scanning will become the first procedure to be performed in children suspected of having an abdominal or pelvic mass, and it may be the only one needed in some cases.

Specific advantages of CT scanning suggested by our study are: (1) CT may offer information regarding both the intraperitoneal and extraperitoneal tissues. It is especially helpful in the investigations of the liver and biliary tract without contrast media. (2) It can show small differences in x-ray absorption and identify masses in or adjacent to other structures of 'water density' not defined by conventional radiography. It differentiates cystic from solid structures. Its ability to show minute calcifications within cer-

tain masses not seen by conventional radiographic techniques has been valuable in this study. (3) The size of a lesion is a limiting factor for CT. Small metastatic foci in the liver and a small (1 cm in diameter) para-aortic node infiltrated with neuroblastoma were missed. (4) It is likely that the IVP will remain superior to CT in better defining intrinsic abnormalities of the collecting system of the urinary tract.

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Correspondence to Dr John C. Leonidas, Department of Radiology, Boston Floating Hospital, 171 Harrison Avenue, Boston, Massachusetts 02111, USA.