LIVER SPLEEN SCINTIGRAPHY IN THE ASSESSMENT OF BLUNT ABDOMINAL TRAUMA IN ADULTS

Vahini Vishnu Naidoo

B.Sc.(UDW), M.B.Ch.B.(Natal)

A Dissertation in Fulfillment of Part Three

of the M.Med (Nuclear Medicine)

Submitted to the University of Cape Town

1994

DECLARATION

I, DR. Vahini Vishnu Naidoo, hereby declare that the work on which this thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other University.

I empower the University to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signed by candidate

SIGNATURE

09/6/94

DATE

June

Acknowledgements

To Professor J Knottenbelt, my supervisor in trauma, for his interest, constructive guidance and prompt review every step of the way.

To Dr AB Fataar, the supervisor in Nuclear Medicine, Dr BK Adams & Prof MD Mann for reviewing this document.

To the staff of the trauma unit, Groote Schuur Hospital for referring patients for liver spleen scintigraphy.

To all the radiographers in the Nuclear Medicine Department, Groote Schuur Hospital for their invaluable role.

To my friend, Dr. Allison Horsell, for interpreting the radiological illustrations and for her moral support.

To my children, Kamil and Namitha, who sacrificed many precious hours of our special time together thus enabling me to complete this dissertation.

To my husband Zayne, for his unlimited patience, support, persistence and guidance throughout this dissertation and the four years in Nuclear Medicine and without whom I would never have had the courage to continue.

CONTENTS

CHAPTER 4: RESULTS

CHAPTER 5: DISCUSSION & CONCLUSION

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

SCINTIGRAPHY

The role of scintigraphy as a diagnostic aid in patients sustaining blunt abdominal trauma has been well established by other authors (6,9,41,42,55,87,92, 96,97,99, 109,132,150). The limitations of planar gamma camera imaging have largely been overcome by the advent of Single Photon Emission Computed Tomography (SPECT) which enhances diagnostic accuracy due to improved resolution (13,15,21,22,70,77,78,79,80,96,117, 139,163). Scintigraphy consists of radionuclide angiography or dynamic imaging which provides functional information (ie. blood flow) followed by a planar or SPECT study which provides anatomical information about the organs of interest.

In the early 1970's, radionuclide imaging was the first technique to be widely used in the detection of liver and spleen trauma. This procedure is well-tolerated and rapidly performed, demonstrating the size, position and configuration of the liver and spleen (59). The use of ultrasound and CT was introduced in the late 1970's and these have established themselves as powerful tools in the investigation of traumatic injuries. These three imaging modalities are the most commonly used ones in blunt abdominal trauma (73,80). SPECT imaging has improved both lesion contrast and anatomical definition and is now considered to be comparable to CT and ultrasound in the evaluation of focal hepatic disease (117,163). Although SPECT is widely available many medical centres have been slow to introduce it into clinical practice (79).

The aim of this study is to show that a simple, non-invasive radionuclide study can be of benefit if used in the appropriate clinical setting. The study was designed to determine the incidence of traumatic lesions to the liver and spleen in patients who do not require urgent surgery and are admitted with suspected liver and/or spleen trauma.

The liver plays a major role in protein, carbohydrate and lipid metabolism, detoxification and hormone synthesis. Therefore the physiological status of the patient following blunt trauma to the liver is acutely altered due to the disturbance in liver function and the presence of complications such as haemorrhage and biliary leaks (28). The major role of the spleen is immunological and trauma to this organ has less effect on the physiological status than liver injury, although haemorrhage from the spleen may be severe enough to cause shock.

BLUNT ABDOMINAL TRAUMA

Blunt trauma to the abdomen is a common surgical problem, with a reported mortality in most clinical series of at least 10% (3,35,73,97,129). Aggressive resuscitation at the accident site as well as in the emergency room, early diagnosis and prompt treatment are essential if this high mortality is to be reduced and preventable deaths avoided. It has been reported that 20-30% of all trauma deaths occurring soon after admission are potentially preventable (36). Unrecognised injury to solid and hollow intra-abdominal viscera remains a frequent cause of death and therefore diagnostic techniques must be constantly reviewed in order to assess their effectiveness in the early diagnosis of organ damage.

Studies in South Africa and the USA have found trauma to be the leading cause of death in patients under the age of 40, with adult males forming the largest component of this group (19,20,28,33,34,43,151,161).

In adult trauma practice 50% of abdominal injuries follow blunt trauma to the abdomen and lower chest and this figure rises to 90% in paediatric practice (24,46,75,84).

The liver due to its size, relative fixation, poor elasticity and compressibility, is often injured in blunt abdominal trauma (59). In different series the mortality from blunt trauma to the liver ranged from 10% to 60%

(28,111,120,134,155). In contrast to simple penetrating injuries which cause minimal tissue devitalization with mild haemorrhage (unless a major vascular structure has been transected), blunt injury to the liver disrupts the parenchyma extensively, causing severe haemorrhage (2,20,34,148,154). Diffuse haematomata or deep areas of devitalized tissue are often not evident, even at surgery (59).

During 1989, records show that 32 000 patients were seen in the trauma unit at Groot Schuur Hospital, Cape Town. The cause of trauma was assault in 50% of cases, whilst 30% was due to domestic violence, 16% to motor vehicle accidents and 4% to sports injuries. Of the 50% due to assault, half were due to blunt trauma and half to penetrating trauma, whereas 90% of the cases due to domestic violence were blunt injuries and 10% due to penetrating injuries (Knottenbelt J Prof, personal communication).

Interpersonal violence is the commonest cause of blunt abdominal injury in South Africa (151). Motor vehicle accidents are the second major cause, whilst sport injuries, falls from heights (>1m) and industrial accidents are less common. This differs significantly from the United States where high speed motor vehicle accidents are a far more common cause of abdominal trauma, accounting for 60 to 75% of cases (28,33,97).

Pathophysiology

Management of the patient with blunt abdominal trauma requires an understanding of the mechanisms of injury. Generally, injuries maybe classified as high energy or low energy depending on the energy imparted to the patient.

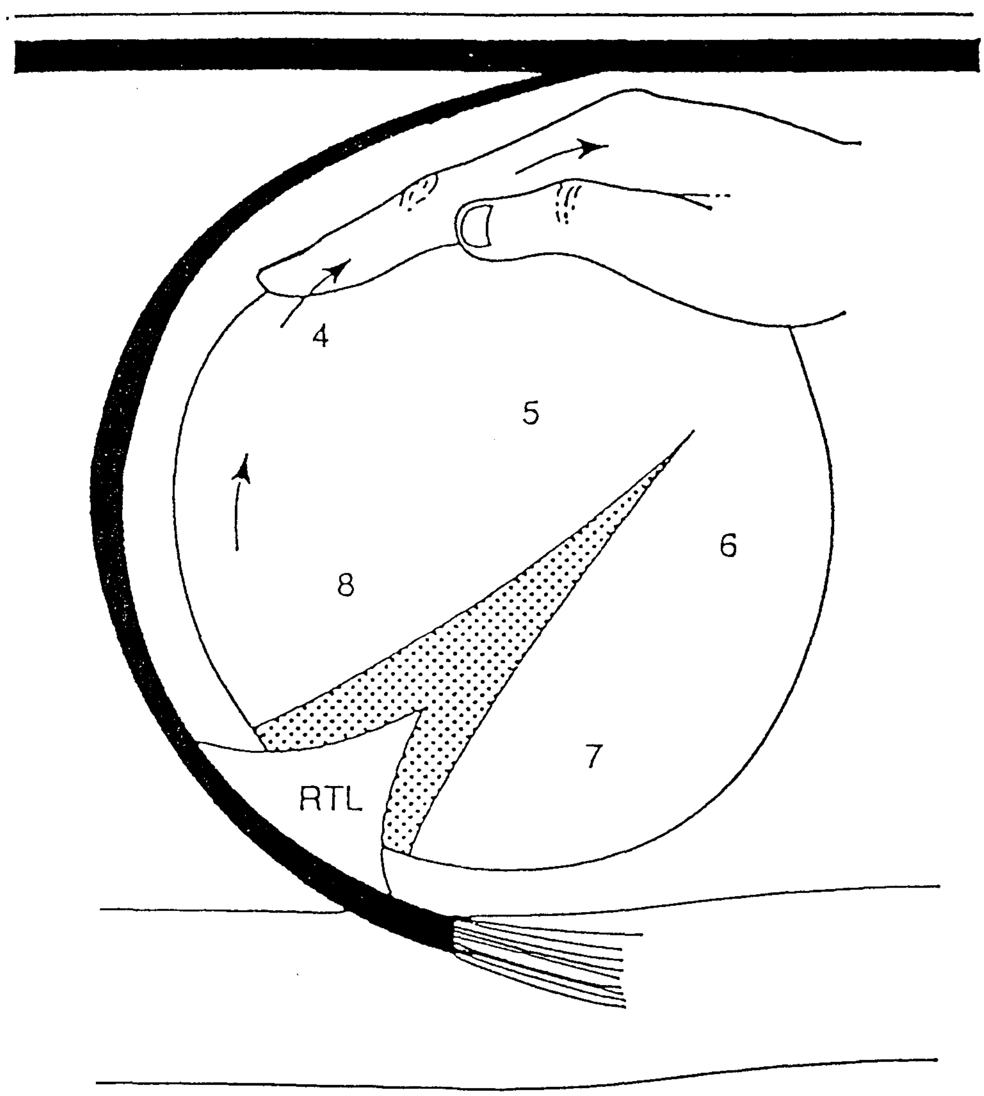
Several pathophysiological processes are operational:
(1) sudden massive rise in intra-abdominal pressures created by outward forces can cause burst injuries of a solid organ or rupture of a hollow viscus,
(2) compression of abdominal viscera between the applied force to the anterior abdomen and the posterior thoracic cage or vertebral column can produce a crush injury,
(3) rotational or shearing forces can cause a tear of the vascular pedicle or the ligaments which attach the organ to the body cavity.

The severity of the injury is related to the force and duration of impact, the area of contact and the mass of the patient (97,99,147).

Three main forms of blunt trauma which affect specific areas of the liver can be identified. (i) Horizontal deceleration injury which frequently occurs during motor vehicle accidents where the liver is violently displaced forwards, (ii) the frontal crush injury which follows a direct blow to the anterior surface of the liver and (iii) vertical deceleration injuries due to falls from a height.

Horizontal deceleration injury results in fracturing along the insertion of the right triangular ligament, which is the natural restraint of the liver to the diaphragm (Fig 1). This corresponds to the plane of the right portal fissure, separating Coinauds segments 6 and 7 (115), from the rest of the liver. Frontal crush injury results in damage to the central segments 4,5 and 8 (137) (Figure 3). With vertical deceleration injuries retroperitoneal haemorrhage is the main cause of ongoing blood loss whereas with horizontal deceleration injuries intra-peritoneal haemorrhage is more likely (130). It is important to differentiate between the forms of injury, as the spectrum of injuries sustained, their presentation, treatment and outcome differ considerably (35,130,138,147).

Figure 1: Schematic diagram of mechanism of deceleration type of liver injury depicting the liver from the right lateral view. RTL= right triangular ligament (from: Sherlock & Bismuth. Secondary surgery for liver trauma) (137)



Clinical presentation - "The Surgical Dilemma"

The symptoms and signs of patients who sustain blunt trauma to the abdomen are notoriously non-specific and are often masked by associated injuries to the pelvis, chest, spinal cord and head. Pain from fractured ribs or a fractured pelvis may also be referred to the abdomen, hindering the clinical evaluation of intra-abdominal organs. An altered sensorium due to drugs, alcohol or head injury makes the findings on clinical examination difficult to interpret.

Abdominal pain is an important symptom of visceral injury and may be referred to the right or left shoulder suggesting liver or spleen injury respectively. The diaphragm and shoulders are both innervated by the afferent fibres of the phrenic nerve and therefore irritation of the diaphragm results in pain being referred to the shoulders.

Abdominal guarding and tenderness are the most frequent signs of injury, whilst rigidity or rebound tenderness are clear signs of peritonitis. Abdominal distension with dullness to percussion is highly suggestive of on-going intra-abdominal haemorrhage, as is the need for repeated blood transfusions in the absence of any other source of bleeding. Ileus or unexplained shock are also indicators of intra-abdominal injury (39). In the unconscious or polytraumatised patient clinical signs are obscured and therefore a high index of suspicion of an intra-abdominal injury must be maintained by the clinician.

The only sign of blunt abdominal trauma may be local tenderness due to abdominal wall abrasions or contusions (39). Abdominal wall contusions are more significant than abrasions as they have been found to be more frequently associated with internal injuries.

Studies have shown the accuracy of abdominal examination following trauma to range from 50% (17) to 65% (132). Normal vital signs on admission do not necessarily predict the absence of potentially life-threatening haemorrhage. Ongoing clinical evaluation of the patient, may not localise the exact site of the injury, but is still the mainstay of management in blunt abdominal trauma. Abnormal vital signs at any point after admission require investigation to rule out significant intra-abdominal injury as these may manifest up to 15 days after the initial insult (5).

Patients who have sustained a head injury severe enough to make them unable to obey simple commands and in whom an occult abdominal injury cannot be excluded should be investigated to exclude intra-abdominal injury (17,18, 39,90).

Liver-spleen scintigraphy is organ specific, but if injuries to other organs are suspected multi-organ radionuclide imaging, a concept introduced by Berg (9), may be performed. Renal injury may co-exist with a liver or spleen injury and either mask the liver-spleen injury or be masked by it.

Different series have reported a range of 13% (33) to 27% (2) of renal injuries associated with liver-spleen damage in patients who have sustained blunt trauma to the abdomen. The most frequent injury associated with damage to the lower pole of the spleen or avulsion of the splenic pedicle is injury to the ipsilateral kidney. Right renal injuries may be associated with extensive injuries to the right lobe of the liver (58,62,143). In a patient with blunt abdominal trauma, the slightest suspicion of renal trauma, which is more common in children, necessitates further investigation (143,145). Therefore, if renal injury is suspected a renal agent such as ^{99m}Tc-DTPA (diethylenetriamine penta-acetic acid) injected immediately after the liver-spleen imaging is completed, can be used to image the kidneys.

Studies have shown that at least 15% of patients with a liver injury will have a serious concomitant injury of the spleen, bowel or diaphragm (32,33,40). It has also been reported that 10% of abdominal injuries due to blunt trauma will have an associated craniocerebral injury and 14% will have long bone fractures (24).

The accuracy of liver-spleen scintigraphy in the acutely traumatized patient has been demonstrated in several studies (4,6,9,30,31,42,44,45,56,58,59,150). With a ^{99m}Tc-tin colloid study the liver and spleen are imaged simultaneously and positive results will determine the further management of the patient whereas a negative scan in a stable patient will obviate further investigation (99). Therefore, the use of an imaging modality which detects alterations in both the physiology and anatomy of the organs of interest is beneficial to the management of the acutely traumatized patient.

Classification of liver and spleen injuries

There are several classifications of liver and spleen injuries with management of the patient dependent on the level of injury sustained. A review of the literature confirms that there is no universally accepted approach to the classification of liver and spleen trauma. Table 1 and Table 2 outline the most widely accepted classifications.

Table 1 : Classification of liver injury and severity

GRADE	SEVERITY OF THE INJURY	FREQUENCY (%)
I	Capsular avulsion Parenchymal fracture < 1cm deep	15
II	Parenchymal fracture 1-3cm deep Subcapsular haematoma < 10cm diameter Peripheral penetrating wound	55
III	Parenchymal fracture > 3 cm deep Subcapsular haematoma > 10 cm Central penetrating wound	25
IV	Lobar tissue destruction Massive central haematoma	3
V	Retrohepatic vena caval injury Extensive bilobar disruption	2

(53,106)

Table 2 : Classification of splenic injuries

GRADE		INJURY DESCRIPTION
I	Haematoma	subcapsular, non-expanding, <10% surface area
	Laceration	capsular tear, nonbleeding, <1cm parenchymal depth
II	Haematoma	subcapsular, nonexpanding, 10-50% surface area intraparenchymal, nonexpanding, < 2cm in diameter
	Laceration	capsular tear, active bleeding
III	Haematoma	subcapsular, > 50% surface area, or expanding Ruptured subcapsular haematoma, active bleeding intraparenchymal haematoma, > 2cm
	Laceration	> 3cm parenchymal depth or involving trabecular vessels
IV	Haematoma	Ruptured intraparenchymal haematoma, bleeding actively
	Laceration	Laceration involving segmental or hilar vessels producing major devascularization
V	Laceration	completely shattered spleen
	Vascular	hilar vascular injury that devascularizes spleen

(132)

Treatment of liver and spleen injuries

In the last decade there has been a trend towards a far more conservative approach in the treatment of intra-abdominal trauma (41,43,45,48,51,65,67,83,103,105,148,149,156,160). Despite improved anaesthetic techniques and post operative care, resulting in a drastic decline in the complications of surgery, a negative laparotomy still carries a mortality of 0.5-6.3% and a morbidity of 5-23% (17,146). Non-operative therapy places a greater responsibility on the surgeon as continued surveillance of the abdomen is the only means of excluding the delayed onset of symptoms (65,82). Continued surveillance should include both regular clinical examinations and the use of accurate non-invasive diagnostic imaging techniques, such as computed tomography (CT), ultrasonography and scintigraphy. Liberal use of these techniques has enabled up to one-third of patients with liver trauma to be managed non-operatively (3,43,69).

The rationale for the previously adopted aggressive approach to splenic injuries was the belief that the traumatized spleen, if not removed would slowly enlarge because of continued slow bleeding and then rupture (92). Studies have shown that the occurrence of delayed splenic rupture is rare (67,109,112,129,132).

This change to a more conservative approach was first adopted by paediatric surgeons following increasing reports of overwhelming post-splenectomy sepsis in children, and subsequently in adults. Sepsis in the asplenic patient carries a 50-75% mortality rate (25,46,101). It has been shown that bleeding from intraparenchymal lesions where the splenic capsule remained intact, or minor capsular tears frequently stops spontaneously, making non-operative management successful in carefully selected patients (46,48,53,100). Mandatory splenectomy has been replaced by attempts at various forms of splenic salvage including splenorrhaphy, partial splenectomy or heterotopic autotransplantation, especially in children (1,25,101).

Autotransplantation of splenic remnants at laparotomy may lead to the salvaging of functioning splenic tissue and therefore provide some protection against overwhelming sepsis, but animal studies have shown that the immune function of autotransplanted splenic tissue is inferior to that of the normal spleen, and therefore, vaccination and prophylactic antibiotics are still required to prevent overwhelming sepsis (101). Splenic remnants will take up the radiopharmaceutical and be imaged as fragments of splenic tissue in the region of the splenic bed.

Eighty-five percent of all liver injuries are minor (7,34) and bleeding abates spontaneously or is readily managed using simple conventional haemostatic procedures. Severe blunt trauma to the liver tends to cause a bursting type of injury and can involve major hepatic veins (20). In some cases there is a clear indication for emergency laparotomy and often persistent haemorrhage from a liver laceration requires surgical intervention, although not necessarily hepatic lobar resection (3,34,53,66,106, 107,131).

Recently, treatment of severe liver injuries has favoured alternatives to major parenchymal excision to achieve haemostasis (111,134,146). Hepatotomy with direct vessel ligation, selective hilar devascularization, and liver packing (47) are techniques employed in an attempt to salvage the liver. The main cause of death in liver and spleen trauma continues to be uncontrolled haemorrhage following severe trauma. If haemostasis is achieved most liver and splenic injuries will heal rapidly (57,113). The natural history of liver injuries which are managed non-operatively is a dimunition in the haemoperitoneum, decrease in parenchymal disruption and resorption of any intrahepatic haematomata (43).

CHAPTER 2 : IMAGING OF THE LIVER AND SPLEEN

ANATOMY OF THE LIVER AND SPLEEN

Liver

The liver is the largest organ in the body, situated in the right upper quadrant of the abdominal cavity, and extending across the midline. The liver is wedge-shaped tapering into a slender structure at its left extremity. Although the upper part is well protected by the lower ribs, the friable and highly vascular nature of the liver parenchyma makes it prone to laceration. Damage therefore may result in considerable haemorrhage .

The liver arises as a diverticulum from the ventral surface of the foregut. Two solid buds of mesenchymal cells develop from this diverticulum forming the right and left lobes, between which there is no vascular communication. The liver parenchyma is supplied by end arteries, branches of the left and right hepatic arteries, and the portal vein (62).

From the anterior view the liver can be externally divided into right and left lobes along an embryological plane which runs along a line connecting the inferior vena cava to the gallbladder fossa. The caudate and quadrate lobes are located medial to the gallbladder fossa, and hence are considered part of the left lobe. The dome of the liver forms the superior contour of the right lobe. Medially, the diaphragm produces a concavity on the surface of the liver.

The falciform ligament extends from this area down to the notch made by the ligamentum teres in the inferior border. The hepatic veins exit at the junction of the dome and this medial concavity, occasionally causing an identifiable indentation. The porta hepatis is found lateral to the falciform ligament. The gallbladder fossa is located on the lower margin of the right lobe of the liver. The renal fossa is situated posteriorly and indents the posterior aspect of the right lobe of the liver. The inferior edge of the liver may be lobulated, concave, convex or straight. A notch is sometimes seen between the right and left lobes of the liver which is due to the thickened inferior margin of the falciform ligament. The left lobe is considerably thinner than the right and may be highly variable in appearance and size (62,145).

A spectrum of variations occurs in the configuration of the liver of adults (108). A large left lobe, occuring in 12% of normal livers, tends to give the liver a quadrilateral shape in the anterior view and is due to persistence of foetal proportions from lack of a lag in its growth. Riedels lobe, which occurs in 4% of normal livers is a downward extension of the right lobe of the liver along the right end of the inferior margin. A domed or high right lobe of the liver called a "en chapeau des gendarmes" or "policemans' hat" is found in 14% of normal livers (72). It is due to an unusually high arching right hemi-diaphragm. (Fig. 13a-g)

Spleen

The spleen is a solid, ovoid shaped organ enclosed in a fibrous capsule. It lies below the diaphragm, in the left upper quadrant of the abdomen between the 9th and 11th ribs with its long axis lying parallel to the 10th rib.

The spleen develops from several buds of mesenchyme in the dorsal mesoderm which fuse forming a single organ. This gives it a lobulated appearance in children. With growth these lobulations disappear and the only remnant of these embryological splenules is the notch which is seen on the anterior border of the spleen (145).

The hilum of the spleen, which is enclosed within the lieno-renal ligament, lies in the angle between the stomach and the left kidney and makes contact with the tail of the pancreas. The splenic artery and vein enter and leave via the hilum. Due to its embryological development each segment of the spleen has its own blood supply with very little communication between segments (62).

The spleen is subject to various anomalies of development including complete agenesis, multiple spleens or splenunculi and persistent lobulation (102). This is important as these variations in the configuration of the spleen may be misinterpreted as pathological when the spleen is imaged (59). Complete absence of splenic tissue is rare and previous splenectomy must be excluded in these patients. The spleen can vary in position due to relaxation of the suspensory ligaments or displacement by gastric dilatation (109).

IMAGING MODALITIES

There have been major technical advances in the field of diagnostic imaging of the liver and spleen over the past two decades. As a result a more conservative approach to the acutely traumatized patient has become widely accepted, based on the availability of these imaging modalities at major trauma referral units (9,16,75,96,). The rational use of various imaging devices should be dictated by the clinical setting. Duplicating studies with similar characteristics adds little to the diagnostic process and may cause confusion.

With an array of imaging modalities available to the physician, selection of the appropriate one for each patient should be based on:

1. the availability of equipment
2. the cost-effectiveness of each study
3. the safety and non-invasiveness of the procedure
4. the radiation dose to the patient
5. the availability and expertise of the physician interpreting the images
6. the impact that the information gained from the study has on the management of the patient.

There are five imaging modalities currently used in the assessment of patients with suspected liver and spleen trauma. These are ultrasound, computed tomography, nuclear scintigraphy, magnetic resonance imaging and angiography (9,16).

In a recent review of nuclear medicine on paediatric imaging Gordon has suggested an 'integrated approach' between functional imaging ie. scintigraphy, and radiological imaging which has greater anatomical depth. The interpretation of the functional images paralleled with the anatomical images will lead to an improved understanding of the underlying disease process and will be of greater assistance to the clinician and most of all to the patient (61).

Particularly in blunt trauma, plain X-rays of the abdomen as well as the chest are part of the basic investigation protocol. Plain x-rays of the chest are an essential part of the assessment of patients with abdominal injuries. The findings of rib fractures, a raised hemi-diaphragm, pleural effusions and obliteration of the costophrenic angles, in conjunction with the clinical evaluation, may add to the clinical suspicion of liver and spleen injuries. Abdominal films may reveal important information including fractures of the lower ribs and lumbar transverse processes, free intra-abdominal fluid and retro-peritoneal air associated with duodenal injuries.

SCINTIGRAPHY IN LIVER-SPLEEN TRAUMA

History

The history of nuclear medicine is based on the parallel development of radioisotopes and the advances in instrumentation. In 1937 the first colloid containing a radionuclide administered to humans was thorotrast, an X-ray contrast material containing thorium (60,93). This is a powerful alpha-emitter which irradiates the patient for many years after its administration causing late complications like hepatic fibrosis, cirrhosis and inducing hepatic tumours (59). With the advent of collimated external detectors in the early 1950's ^{131}I-rose bengal replaced thorotrast for hepatic imaging. ^{131}I-rose bengal is not the ideal agent for imaging the liver because of its slow accumulation in the liver, by which time biliary excretion occurs. This results in confusion between hepatic parenchymal pathology and normal gallbladder and duodenal excretion. In addition, it is excreted in the large bowel resulting in a large radiation dose to the gonads (60,93). For these reasons, ^{131}I-rose bengal was superseded by colloidal gold (Au 198). However, the disadvantages of colloidal gold are its long half-life (2.7 days) and high energy gamma rays (411keV) which result in an increased radiation dose to the organs of uptake (60,142).

In 1957 Hal O. Anger working at the University of Berkeley, California, described the first version of the gamma camera.

The Anger camera which revolutionized the practice of nuclear medicine became commercially available in 1962 (29).

In 1958 Brookhaven National Labarotories developed the first technetium generator for general scientific use based on the solvent extraction method from ^{98}Molybdenum. The modern sterile generator as we know it today was only developed in the late 1960's by E. R. Squibb & sons. Once this generator became commercially available it provided a convenient source of readily available technetium (93,122).

In 1963 a heat controlled denaturing method to produce colloid or aggregates of human serum albumin labelled with ^{131}I became popular. Its major advantages over colloidal gold was that it was not permanently retained in the liver and that it had a longer "shelf-life" (86,93,142). It was only after the modern sterile generator became commercially available in the late 1960's, providing a readily available source of ^{99m}Tc, that radionuclide liver imaging was able to be used more widely (93,122).

Refinement of the Anger gamma camera continued, resulting in the single photon emission computerized tomographic (SPECT) device first described by Jaszcar in 1979. It took a further 5 years before this became commercially available (29).

Current radiopharmaceuticals

^{99m}Tc has many favourable radiodosimetric characteristics. It emits gamma rays at 140keV, has a relatively short half-life (6.03 hours), delivers a low radiation dose per gamma ray emitted, has no beta particle emissions and can be used to label a variety of imaging agents. Tin colloid or sulphur colloid labelled with ^{99m}Tc particles are used to image the liver and spleen looking for focal or linear defects in uptake.

Other radiopharmaceuticals commonly used in liver imaging are the imino-diacetic (IDA) group, labelled with ^{99m}Tc. The IDA-analogues are excreted by the hepato-biliary system and can be used in the acute trauma setting to demonstrate or exclude a bile leak (56,58,158).

Selective splenic imaging using ^{99m}Tc-labelled heat damaged red blood cells is based on the unique ability of the spleen to trap damaged red blood cells and there is no uptake by the liver. If a ^{99m}Tc-tin colloid study shows interference from the liver (eg. an overlapping left hepatic lobe) or there is poor radiocolloid uptake in the spleen then a ^{99m}Tc-labelled red blood cell study may be indicated. Another indication for this scan is to detect residual splenic tissue after splenectomy (4).

^{99m}Tc-Tin colloid

^{99m}Tc-Tin colloid was used in this study. It is available for daily use in a shake and mix kit which unlike the sulphur colloid kit, does not require heating. As a result the preparation of tin colloid is more rapid and simpler. The tin colloid particles are smaller and more evenly distributed than sulphur colloid particles and this results in more rapid and greater uptake of this radiopharmaceutical by the liver, spleen and bone marrow (60,86,93).

In addition, renal and gastric uptake at 5 minutes is less with tin colloid than with sulphur colloid as a mere 0.1% free pertechnetate remains after preparation of the tin colloid, leading to minimal renal and gastric uptake. Tin colloid, unlike sulphur colloid, is unaffected by aluminium breakthrough from the technetium generator up to a concentration of 20ug Al^{3+}, but above this level flocculation of the tin-colloid particles does occur (60,86,93,126,128).

Adequate blood flow to the reticulo-endothelial system is a prerequisite for the phagocytosis of radiotracers. The labelled colloid, on first passage following intravenous bolus injection through the circulation, initially passes through the heart and lungs and then via the arteries to the rest of the body. The amount of colloid arriving at each organ on first passage is proportional to the arterial perfusion of that organ. Colloid passing along the hepatic and splenic arteries is removed efficiently by the liver and spleen.

The liver has a dual blood supply with the major component (75%) being from the portal vein and only 25% from the hepatic artery (37,52,145,157). Therefore there is a delay of approximately 15 seconds before blood reaches the liver because the larger proportion of the blood supply (via the portal vein) has to pass through the gut first (52).

The uptake and distribution of ^{99m}Tc tin colloid in the liver and spleen reflects both perfusion and the distribution of functioning phagocytic cells such as the Kupffer cells (which line the hepatic sinusoids) and the macrophages of the spleen and bone marrow in these organs. Normally there is a homogeneous distribution of phagocytic cells in the liver and the spleen.

Factors, other than blood flow to an organ, which affect phagocytosis are - the size, particle number and surface charge of the colloid particles. The average size of the tin colloid particles ranges from 0.3 to 1.0 um and once extracted by the phagocytic cells it undergoes minimal metabolic alteration. Normally about 80% of the injected colloid particles are sequestered by the liver, 15% localizes in the spleen and the remainder appears in the bone marrow (8,86,93).

The radiolabel remains in the phagocytic cells and since there is no biologic turnover, the effective half-life is equal to the physical half-life.

The plasma clearance half time is about 2 to 5 minutes and maximum liver uptake occurs in 5 to 10 minutes. The clearance rate of colloid particles depends on the blood volume perfusing the liver and on the number of particles. In adults, maximum clearance in each passage through the liver is about 94% so that approximately 10 minutes after intravenous injection 97% of the tin colloid particles are distributed in the liver and spleen. The stability of the tracer within the phagocytic cells provides sufficient time for a SPECT study to be completed (126).

The mechanism of localization of the colloid particle is by phagocytosis, a process which is aided by opsonization of these particles (60). Particles coated with an IgG opsonin have been shown to attach to a specific receptor on the phagocyte, called the Fc receptor since it accepts the Fc (carboxy terminal end of IgG) portion of IgG. A receptor has also been identified for complement, the C3 (third component of complement) receptor. The Fc and C3 receptors function independently. The Fc receptor responds only to IgG opsonised familiar material while the C3 receptor can respond to unfamiliar material that may or may not be opsonised with complement (128).

Disadvantages of the 99mTc-Tin colloid scan

It has been found that chlorhexidine gluconate (used to disinfect the skin at injection sites) causes agglutination of colloid particles and may form a technetium gluconate complex thus diverting the radioactivity to the kidneys.

Chemotherapeutic agents are associated with an alteration in hepatic colloid distribution inducing extra-hepatic uptake of radiocolloid by the spleen, bone marrow and lungs (74). Excessive antacid usage has been demonstrated to cause pulmonary uptake of colloid. In patients with iron overload, excessive dietary vitamin A intake, and following recent radiotherapy there is reduced Kupffer cell uptake of colloid (59,126,128). It has been shown that the reticulo-endothelial cells are profoundly affected by radiation yet the hepatocytes are far less sensitive to the same agent (59). Reduction in Kupffer cell activity is seen to correspond to the portal of the radiation field.

Current Status of Scintigraphy

Scintigraphy is a simple, non-invasive, cost-effective and accurate technique used in the diagnosis of hepatic, splenic and renal injuries (6,9,15,31,41, 42,50,69,73). Gilday and Alderson (59) reviewed 162 patients using scintigraphy to evaluate the presence of liver injuries following blunt abdominal trauma. There were no false negatives and a false-positive rate of only 7% was found. In another study by the same authors (59), 202 patients evaluated for a splenic injury using scintigraphy were found to have a false-negative rate of 1,5% and a false-positive rate of 7,2%. These studies and others (6,9,41,42,55) indicate the high sensitivity and specificity of liver-spleen scintigraphy in the evaluation of patients with liver and spleen injury following blunt trauma to the abdomen.

When a radiopharmaceutical is administered by intravenous injection, its distribution is 3-dimensional. Planar imaging of this distribution is a 2-dimensional projection where the distribution is integrated over depth, with contrast decreasing as depth increases. Tomographic imaging is a 3-dimensional projection and therefore more accurate.

The dynamic phase, or scintiangiography, depicts arterial and venous blood flow to the liver in a manner analogous to contrast angiography (37,52). The dynamic phase is used to determine bleeding sites (by looking for extravasation) and to determine the vascularity of a lesion eg. haematomata and cysts are hypovascular, metastases are hypervascular and abscesses show a rim of increased perfusion surrounding a poorly perfusing central area (54,123,157).

The total liver perfusion can be estimated from the rate of clearance of the intravenously injected radiocolloid. The magnitudes of the hepatic artery and portal vein components of hepatic perfusion can be determined by analysing the time variation in liver activity. The arterial and portal components are separated by their times of arrival at the liver. These arrival times are evaluated from time-activity curves for the spleen, left ventricle and left kidney. Therefore quantitation of different parameters is possible (52).

Planar imaging cannot resolve defects in the antero-posterior plane. This is a major disadvantage for a thick organ deep in the abdomen such as the liver and reduces the sensitivity and specificity of planar imaging (114,153).

SPECT measures and displays the concentration of the radiopharmaceutical within a thin slice of tissue leading to improved lesion detection and anatomic localization. The principle of SPECT is that the plane of interest is imaged from many different angles and the activity within one pixel in the reconstruction plane is deduced from all the line integrals passing through that point (11,38,80).

With planar imaging, superficial lesions have to be at least 2cm in diameter and deep-seated lesions (particularly in the right lobe) 3 to 4 cm in diameter to be detected. Lesions smaller than this are not detected leading to a high false negative rate (121,124). With SPECT imaging an area or volume of disturbed function ranging from 1 to 1.5 cm can be detected. This is due to the physiological nature of the study which is sensitive to any disturbance of function in the surrounding parenchyma.

Pitfalls in Abdominal SPECT Imaging

(i) Pitfalls related to the patient

(a) excessive patient size which causes difficulty in positioning the organ of interest within the field of view throughout the entire study; (b) gross patient motion causes image degradation; (c) diseased organs result in reduced uptake of the radiopharmaceutical producing a low target:background ratio and (d) arm attenuation artefacts (152).

(ii) Technical Pitfalls

(a) If a circular rotation orbit is used the detector is further away from the patient in the anterior and posterior positions thus degrading image resolution. Hence it is preferable to use the elliptical rotation orbit for acquisition so that the detector is brought closer to the organs of interest improving the resolution of the images (152). (b) The patients' arms must be out of the field of view of the detector and not alongside the body to allow the detector to get as close as possible to the patient. If the arms are not placed across the chest or above the head this will substantially increase the distance between the detector and the organs of interest. Detector resolution deteriorates by a factor of 2 at a distance of 4 to 5 cm from the patient and therefore the spatial resolution (ie. the sharpness or detail of the image) of the image will deteriorate (141) (c) poor patient positioning by the operator (d) rotational gantry malfunctioning (e) detector non-uniformity and incorrect centre of rotation and (f) faulty reconstruction and filtering techniques.

In order to maintain a high degree of resolution the gamma camera has to be checked and calibrated regularly. Despite this, slight degradation of the images does occur due to the finite spatial resolution of the system and Compton scattered photons. However, corrections for the attenuation of photons and the contribution of scattered radiation are made more easily using SPECT machinery thus improving the contrast resolution of the resultant images (68).

Non-uniformity problems are particularly important in liver-spleen scans as they can produce artefacts which may simulate pathology. Centre of rotation deviations of >3mm can also produce significant image distortion and artefacts. In addition, one or more frame positions may be by-passed due to excess rotation, gantry vibration or problems with the acquisition device.

(iii) Pitfalls in interpretation

Pitfalls in this category can be reduced by the observer being fully acquainted with the normal and pathological anatomy.

As reported in the literature the right lobe of the liver is the most commonly injured site but is difficult to evaluate both scintigraphically and at laparotomy (59). Even with the use of tomographic imaging the presence of linear defects in the dome of the right lobe presents a problem as these defects may be due to Liebermeister's grooves or a liver laceration in the acute clinical setting. Liebermeister's grooves occur in 10% of normal livers and are indentations of the liver produced by aberrantly short, arching bundles of diaphragmatic muscle, seen as linear defects in the dome of the right lobe of the liver. Careful attention to the direction, length and number of defects in the dome of the right lobe may be helpful in establishing if it is due to trauma or a normal variant.

The falciform ligament and medial aspect of the left lobe of the liver are also difficult areas to interpret because of the normal thinning of the left lobe and the inferior margin of the liver thus presenting areas of reduced activity on the scintigraphic images. The porta hepatis is another area of difficulty appearing as a deep broad notch in the inferior margin of the liver producing a defect on the anterior image, which has to be differentiated from true pathology at this site. In one series of 80 suspected cases of pathology in the porta hepatis, 42% of these were found to represent actual pathology in this region (98). In another series a simulated defect in the porta hepatis was found in 50% of cases. Therefore the porta hepatis is a difficult area to interpret and if SPECT findings are ambiguous then a second imaging device like ultrasound or computerized tomography may be helpful (21,22,127).

SPECT imaging has been particularly helpful in areas like the gallbladder fossa, renal fossa, inferior vena cava, porta hepatis and notch of the ligamentum teres where defects may be due to variations in the configuration of portal vein branches and bile ducts, or to impressions created by the costal margins or retroperitoneal organs (121,127,144,152). It is essential that a lesion be identified in at least two of the three orthogonal planes so as to ensure accurate assessment of pathology (144).

One of the disadvantages of the high target-to-background contrast obtained with SPECT, is that normal intrahepatic vessels of approximately 2cm in diameter may appear as distinct focal "defects" in tomographic sections throughout the liver. This can be overcome by examining these "defects" in multiple orthogonal planes together with a thorough knowledge of the vascular anatomy, thereby reducing the number of false positives (68,109,117,118,144).

Unlike the liver, variations in shape and distribution of activity within the spleen do not simulate defects (92). Marked persistent clefting, which is estimated to occur in 2% of individuals can give the spleen a lobulated appearance (64).

RADIATION DOSIMETRY

The increasing use of various forms of radiation in medicine (x-rays, radiotherapy and nuclear medicine) contributes to the total radiation burden of the general public. Increasing awareness of radiation safety has become necessary and the International Commission on Radiological Protection (ICRP) has suggested the following guide-lines for dose limitation :

(i) procedures should only be done if they offer a net positive benefit to the patient

(ii) accounting for the risk/benefit and socio-economic factors, all exposures should be kept As Low As Reasonably Achievable (ALARA)

(iii) the dose equivalent limits for the various procedures as described by the ICRP should not be exceeded.

The maximum permissible dose or dose equivalent limits as proposed by the ICRP with reference to patients (ie. non-occupational) is a total body dose of 5mSv per year.

The radiation received by various areas of the body using ^{99m}Tc-tin colloid is listed in Table 3.

Table 3: Radiation absorbed dose estimates (mrad/uCi)* in adults from standard doses of intravenously administered 99mTc-tin colloid**

AREA OF BODY	RADIATION ABSORBED DOSE (mrad/uCi)*
TOTAL BODY DOSE	0.01 - 0.02
RED BONE MARROW	0.02 - 0.03
GONADS	0.01 - 0.02
LIVER	0.2 - 0.4
SPLEEN	0.2 - 0.4

adapted from Sorenson & Phelps. Physics in Nuclear Medicine. 2nd ed. p561 (141)

* to obtain absorbed dose in mGy/MBq, divide values by 3.7

** standard dose of ^{99m}Tc-tin colloid = 4-6mCi (148-222MBq)

OTHER DIAGNOSTIC PROCEDURES TO DETECT LIVER-SPLEEN TRAUMA

Several authors have examined the role of scintigraphy in liver or spleen injury while others have evaluated both ultrasound and computerised tomography.

Liver-Spleen scintigraphy (6,9,10,55,69,85,88,109,119, 149,150,159) and computerised tomography (10,27,45,69,76 81,105,110,116,135,161,163) are both accurate in the detection of liver and spleen injuries. Simultaneous interpretation of liver-spleen scintigraphy and computerised tomography of the liver is more beneficial than independent interpretation and they should be regarded as complementary rather than competitive modalities (6,9,16,94,163,164).

With a contusion, there is no clearly demarcated plane between normal and contused tissue and therefore it is difficult to detect a contusion using US or CT. However, scintigraphy, where uptake is based on the disturbance in function, can easily detect a contusion as it is not dependent on a clearly definable interface between normal and abnormal parenchyma. In the acute stages, there is very little difference between interstitial and intravenous blood and therefore even if a CT scan is done using contrast, a contusion may be missed.

Trauma along the plane of the falciform ligament may result in slight widening of this area. This slight anatomical change cannot be detected by US, but because the falciform area is an end-arterial zone, the damage can be detected by scintigraphy.

Ultrasound

The principle of ultrasound is that it produces images by transmitting a sound pulse through tissues and then detects the amplitude and depth of the reflected sound. The reflection of sound waves is dependent on the interfaces between tissues with different acoustical properties. The degree of echogenicity, which is always compared with the normal surrounding parenchyma, depends on the amount of reflected versus absorbed ultrasound waves (125).

Diagnostic ultrasound is used in many centres as the investigation of choice for intra-abdominal injury, particularly in children (12,23,46,49,63,89). It may be used to image the entire abdomen, detecting intra-abdominal haematomata and intraperitoneal fluid. However rib fractures, abdominal wall tenderness and gaseous distension of the abdomen, often present in patients with a suspected intra-abdominal injury, may make ultrasonography difficult resulting in a sub-optimal scan of poor diagnostic quality in at least 10-20% of cases (55). Generally, ultrasound is more useful in children in the acute phase but is also used in the follow-up of lesions which were initially detected by computerized tomography. It is also more cost-effective to follow-up patients with ultrasound or scintigraphy than with computerized tomography or magnetic resonance imaging (14,55,75,132).

Computerized Tomography (CT)

Data obtained by computerized tomography is derived from differences in tissue densities and the related attenuation of transmitted x-rays. To determine the vascularity of lesions, iodinated contrast can be administered during the computerized tomography study. Iodinated contrast cannot be used in patients who are iodine sensitive and in patients with renal failure (125) and this can be a limiting factor.

Computerized tomography is often the most utilised of all of the imaging modalities available for the evaluation of the acutely injured patient (45,63,71,94,105,110,116,135). The liver can be evaluated in approximately 10 minutes using modern equipment (162). With its high resolution, images of excellent anatomic detail are produced. Other advantages include being able to image the abdominal contents in a single study, the accurate detection of small amounts of free intraperitoneal blood or air and the localization of bony structures (63). With contrast administration the vascular integrity of various organs can be assessed (3,6,10,14,132).

Two major perceived advantages of CT are its ability to detect intra-peritoneal blood and it superior anatomical resolution. Lutzker, however, has stated that the detection of intra-peritoneal blood is of no more clinical importance than the demonstration of intraparenchymal extravasation on angiography and that the superior resolution is of little clinical value since the decision to operate is based on the clinical status of the patient rather than the demonstration of organ damage (92).

The disadvantages of computerized tomography are:- the higher radiation dose required compared to other imaging modalities, artefacts produced due to patient motion which interfere with the quality of the image produced, and a higher cost (92). Although respiratory movement influences both computerized tomography and scintigraphy, the scintigraphic images are less affected. With SPECT imaging the hepatic movement during respiration at rest is approximately 1.3cm which will reduce lesion detection. Motion correction by computer processing or increasing the average count rate per image during acquisition will improve the number of lesions detected (9,27,144).

Adequate sedation in a restless patient is needed in order to acquire a technically satisfactory study and this is more often necessary with computerized tomography than with scintigraphy. The design of the gamma camera allows for a restless patient to be held down if necessary, as this may be preferable to administering a sedative which may mask vital clinical signs in the acute stage (9,27).

Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging demonstrates an abnormal signal intensity from pathological hepatic masses when compared to the normal parenchyma. The degree of signal intensity is dependent on the water and fat content in tissues. The T1 relaxation time is the time required for protons to realign themselves with an external magnetic field after a radiowave pulse is emitted. The T2 relaxation time is the rate at which protons get out of phase due to the effects of adjacent protons. Both T1 and T2 images are obtained to demonstrate various lesions in the liver. The vascular supply of lesions can be visualized by using a contrast agent like Gadolinium-DTPA (125).

To date no comparative study has been done between MRI and scintigraphy although MRI findings have been found to correlate well with surgical findings (162). MRI is expensive and most trauma centres do not have access to this imaging modality at the present time. In addition, the high magnetic field makes it necessary to use special non-ferromagnetic resuscitation equipment and ventilators. Currently magnetic resonance imaging is not a suitable imaging modality in the acutely injured patient.

Angiography

The use of angiography is based on the fact that certain hepatic masses are supplied primarily by the hepatic artery

(125). It is invasive and therefore its use in the routine evaluation of a patient with acute abdominal injuries is limited. If computerized tomography detects disruption to the vascular integrity of a particular organ, surgical exploration is preferred as the next step, rather than angiography.Other disadvantages of angiography include its expense, the inability to obtain multiple views and a possible reaction to the contrast.

DIAGNOSTIC PERITONEAL LAVAGE

For at least two decades diagnostic peritoneal lavage (DPL) was the 'gold standard' in the evaluation of acute blunt abdominal trauma (95). Its disadvantages are that it cannot pin-point the organ of damage and is found to be misleading in the presence of pelvic fractures (116,150,159). DPL will yield false negative results with retroperitoneal, early small bowel and diaphragmatic injuries. The negative laparotomy rate following positive diagnostic peritoneal lavage ranges from 6 to 25% (116,140).

In the trauma unit at Groote Schuur Hospital, DPL is still used to exclude significant intra-abdominal injury (clear return) but its high false positive rate limits its usefulness. Laparoscopy with direct visualization of the peritoneal cavity is now replacing DPL, but this requires special instrumentation and expertise.

COMPARISON OF COSTS OF DIFFERENT LIVER-SPLEEN IMAGING MODALITIES

In these stringent financial times it is only prudent to include the cost of the various modalities which can be utilized to image the liver and spleen. Although the cost of the imaging modalities should not be ignored it does not play an overriding role in the selection of an appropriate investigation (16).

Table 4 : COMPARISON OF COSTS OF DIFFERENT LIVER-SPLEEN IMAGING MODALITIES

INVESTIGATION	COST - SCALE OF BENEFITS*
MRI	R2160.00
CT scan	R688.00
Angiogram	R417.60
Ultrasound	R160.00
Scintigraphy	R295.90

* scale of benefits is according to the 1994 RAMS

From this table it can be seen that ultrasound and scintigraphy are the least expensive imaging modalities and therefore can be utilized for both diagnosis and follow-up of traumatic lesions.

CHAPTER 3 : METHOD OF STUDY

Selection of Study Population

All patients admitted between March and December 1993 to the trauma unit of the New Groote Schuur Hospital (NGSH), with clinical evidence of blunt trauma to the chest and abdomen were considered for inclusion into a prospective study. Using strict inclusion criteria, outlined below, 100 consecutive patients were sent for liver-spleen scans to either confirm a strong clinical suspicion of injury to these organs, or to exclude injury to these organs when trauma or the impact of the injury was in the upper abdominal area.

The inclusion of patients in this study was therefore based on the presence of at least one of the following - upper abdominal tenderness, lower rib or pelvic fractures which hindered clinical assessment, an unexplained drop in the patient's haemoglobin level suspicious of on-going intra-abdominal haemorrhage and suspected or confirmed haemoperitoneum.

Patients were arbitrarily divided into two groups after they had been clinically assessed. Grade 1 patients were those in whom, following examination, the medical officer had a high index of suspicion of a liver-spleen injury. Grade 2 patients were those in whom, following examination, the medical officer was unsure of a liver-spleen injury or an injury had to be excluded. In both grades patients who presented with a history suggestive of a liver or spleen injury were included. Patients were included in Grade 1 if they had severe upper abdominal tenderness, guarding of the abdomen, rebound tenderness, painful rib fractures, painful pelvic fractures and a drop in haemoglobin levels. Grade 2 patients had minimal upper abdominal tenderness, minimally tender rib or pelvic fractures and abdominal wall contusions or abrasions. This clinical grading was used in data analysis.

Patients were excluded from this study if they were pregnant, haemodynamically unstable, in need of urgent surgery and if injuries to the upper limb prevented them from raising their arms out of the field of view of the gamma camera detector.

IMAGING PROTOCOL AND TECHNIQUE FOR SCINTIGRAPHY

The 100 patients who met the inclusion criteria for this study were scanned within one week of being injured. The procedure was first explained to the patient and informed consent was obtained. If the patient was found to be extremely restless, a mild intravenous sedative (Midazolam 5mg) was administered. The standard method was used to prepare a dose of 80-100 MBq of ^{99m}Tc-tin colloid.

ACQUISITION

A large field of view GENERAL ELECTRIC 400 AC gamma camera was used. The head of the gamma camera was positioned anteriorly to the patient so that the lower ribs and the upper abdomen were in the centre of the field of view of the detector.

A dynamic sequence followed by a SPECT study was acquired. The dose was administered intravenously using the Oldendorf technique and the acquisition started simultaneously with the injection.

Dynamic data was recorded for 800 seconds at 10 seconds per frame in a 64 x 64 matrix, using a high sensitivity, low energy collimator.

This was followed immediately by the SPECT study using a high resolution, low energy collimator. Images were recorded in a 64 x 64 matrix and 60 step and shoot images were recorded at 6 degree intervals for a total of 360 degrees. The frame time was set at 20 seconds per frame.

PROCESSING

The dynamic study did not require processing of the raw data and the images were recorded as acquired, in 10sec/frame images for 80 frames. The raw data from the SPECT study was processed using commercially available software on the GENERAL ELECTRIC system.

The data was corrected for centre of rotation although no uniformity correction was applied. The method of reconstruction was filtered back-projection using a Hanning pre-filter with a cut-off frequency of $0.8cm^{-1}$ and a ramp back-projection filter. Attenuation correction of the images using an attenuation coefficient of $0.12cm^{-1}$ was carried out.

Transaxial, coronal and sagittal slices of 6.25mm width were generated. Hard copy films were made of the dynamic and SPECT studies.

Patients were followed up at the Surgical Out Patients Clinic and in 8 of the 100 patients a three month follow up scan was requested. These scans were acquired and analysed using exactly the same method as the first scan.

METHOD OF REPORTING NUCLEAR MEDICINE SCANS

The dynamic study was reviewed using a display format allowing the first 16 images to be displayed at once, followed by the next 16 images, and so on till completion. The results were reported describing the nature of the blood flow and the site of the abnormality as seen on the dynamic phase. (Figure 2)

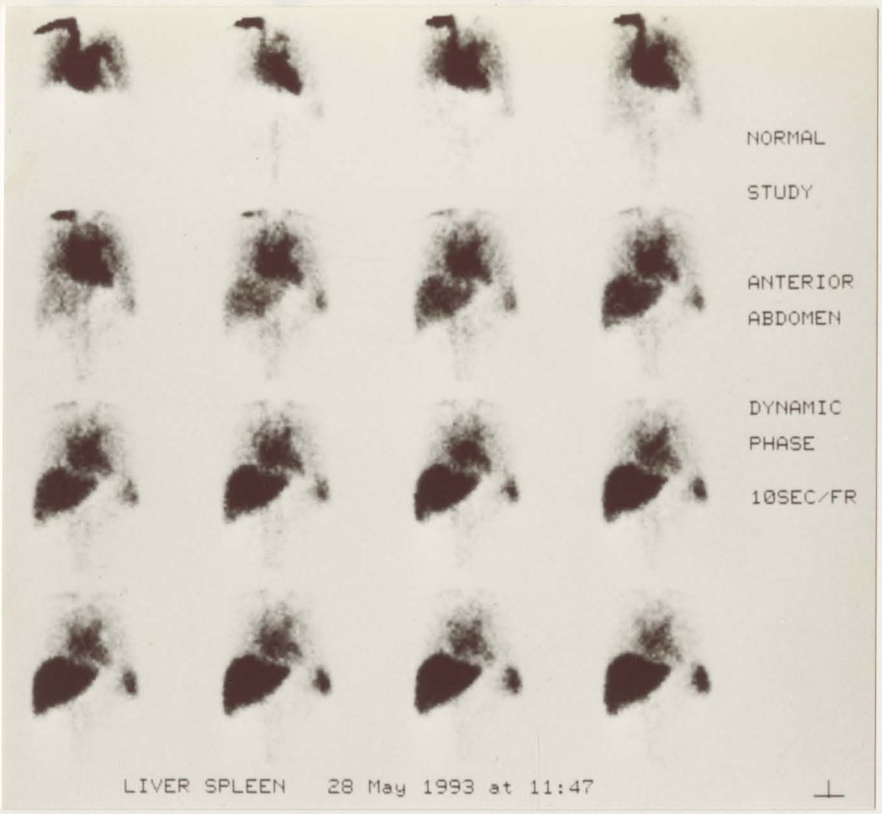
The SPECT study was reviewed using a protocol which allowed viewing of the transaxial, coronal and sagittal images simultaneously (Figure 2).

A systematic approach of reporting each of the 100 cases was used by evaluating the following features on each scan - the size, shape and position of the liver and spleen, the presence of any underlying abnormalities, the homogeneity of activity within these organs, the presence of any focal or linear defects of activity in the liver and spleen and the presence of 'colloid shift' between the liver and spleen.

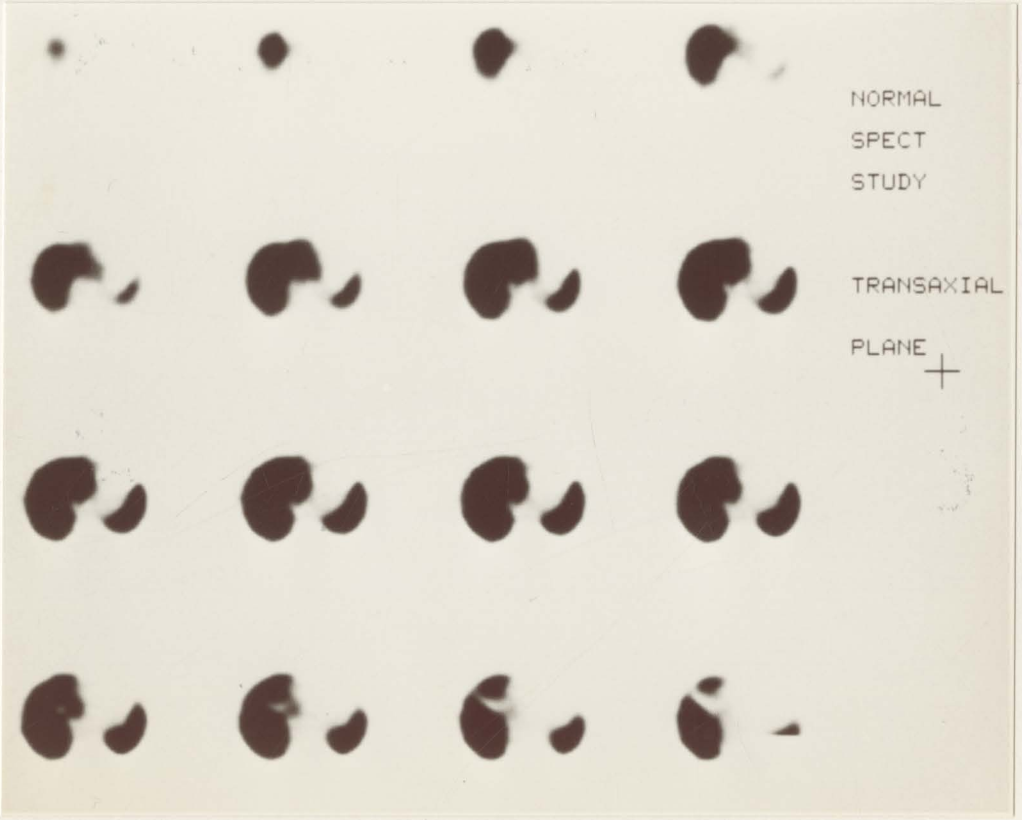
Ruptures in the liver or spleen appear as linear or stellate defects within the parenchyma; contusions as focal areas of reduced perfusion; intraparenchymal haematomata as focal defects; and subcapsular haematomata as semilunar or "thumbprint" indentations on the periphery. In severe injury, multiple fragments of spleen may be seen (102). Lesions were described using these terminologies.

Figure 2 : Dynamic (a) and SPECT (b,c,d,e) images showing a normal 99mTc liver-spleen scan

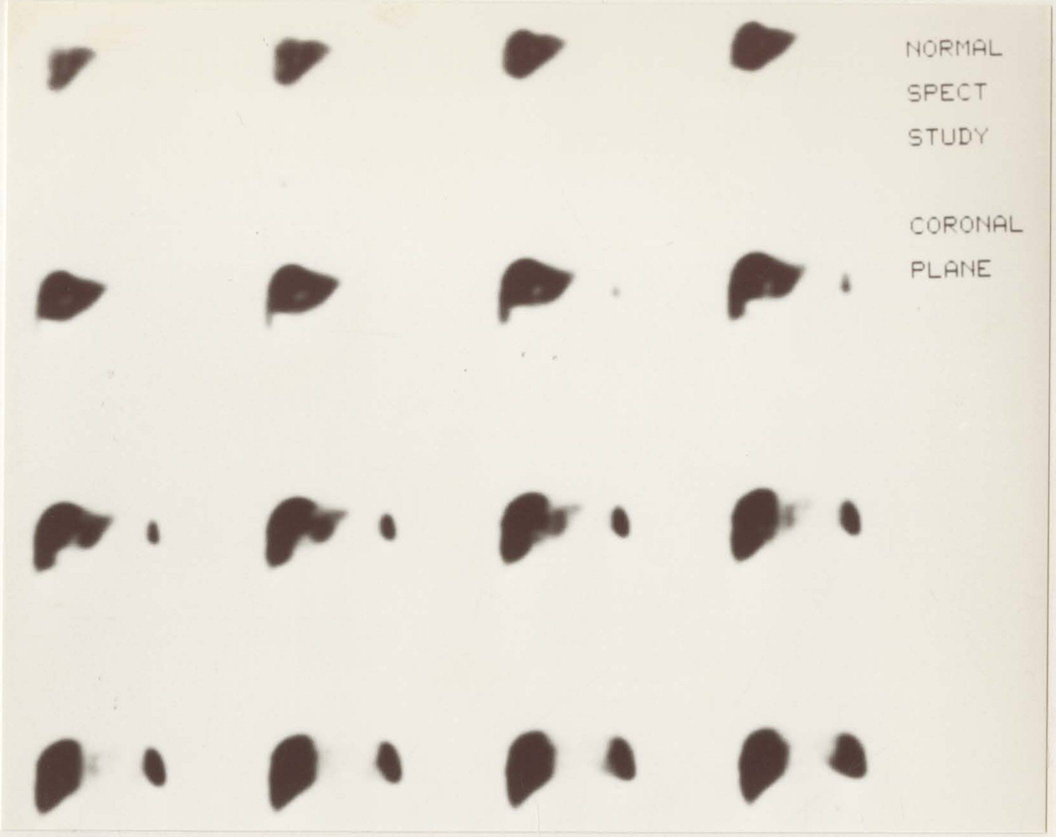
2(a): Dynamic phase (10sec/frame) in the anterior view.



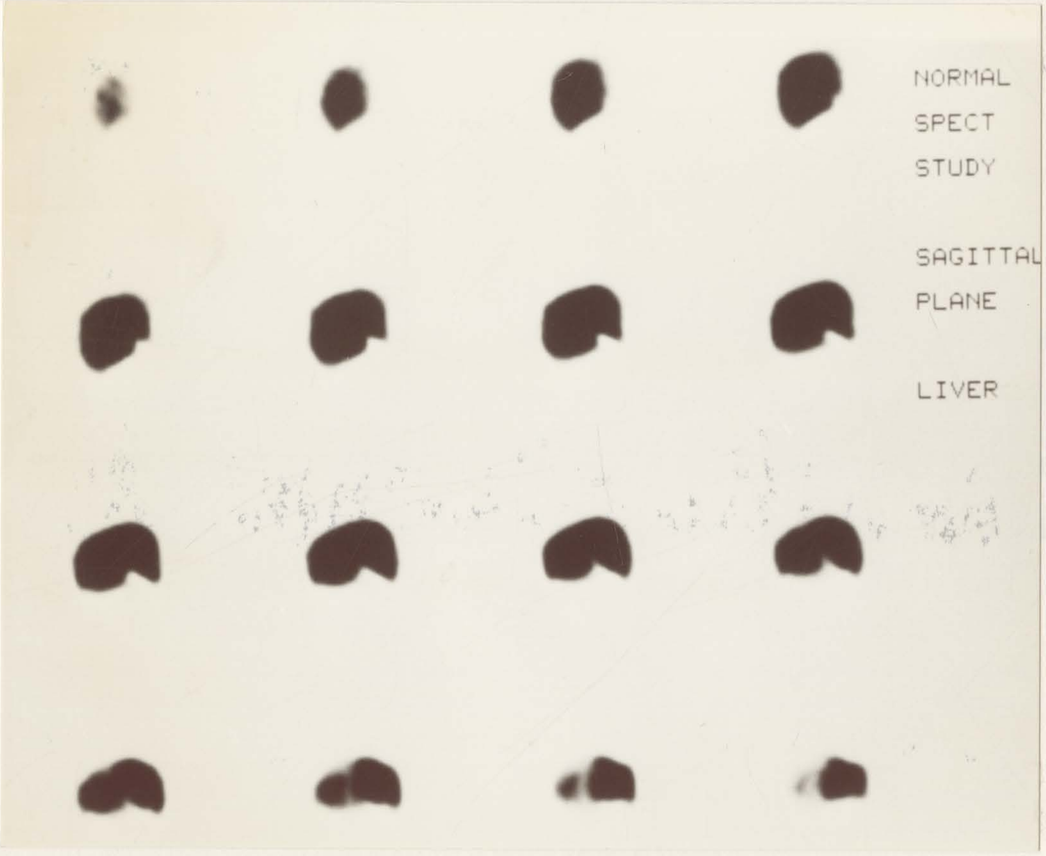
2(b): SPECT images-transaxial plane (superior to inferior)



2(c): SPECT images - coronal plane (anterior to posterior)



2(d): SPECT images of liver - sagittal plane (right to left)



2(e): SPECT images of spleen-sagittal plane (right to left)

In addition, the exact location of the lesions detected on the scans were described according to the segmental anatomy as described by Oyamada, et al. This division of the liver into segments is based on Coinaud's segments which are illustrated in Figure 3 (115).

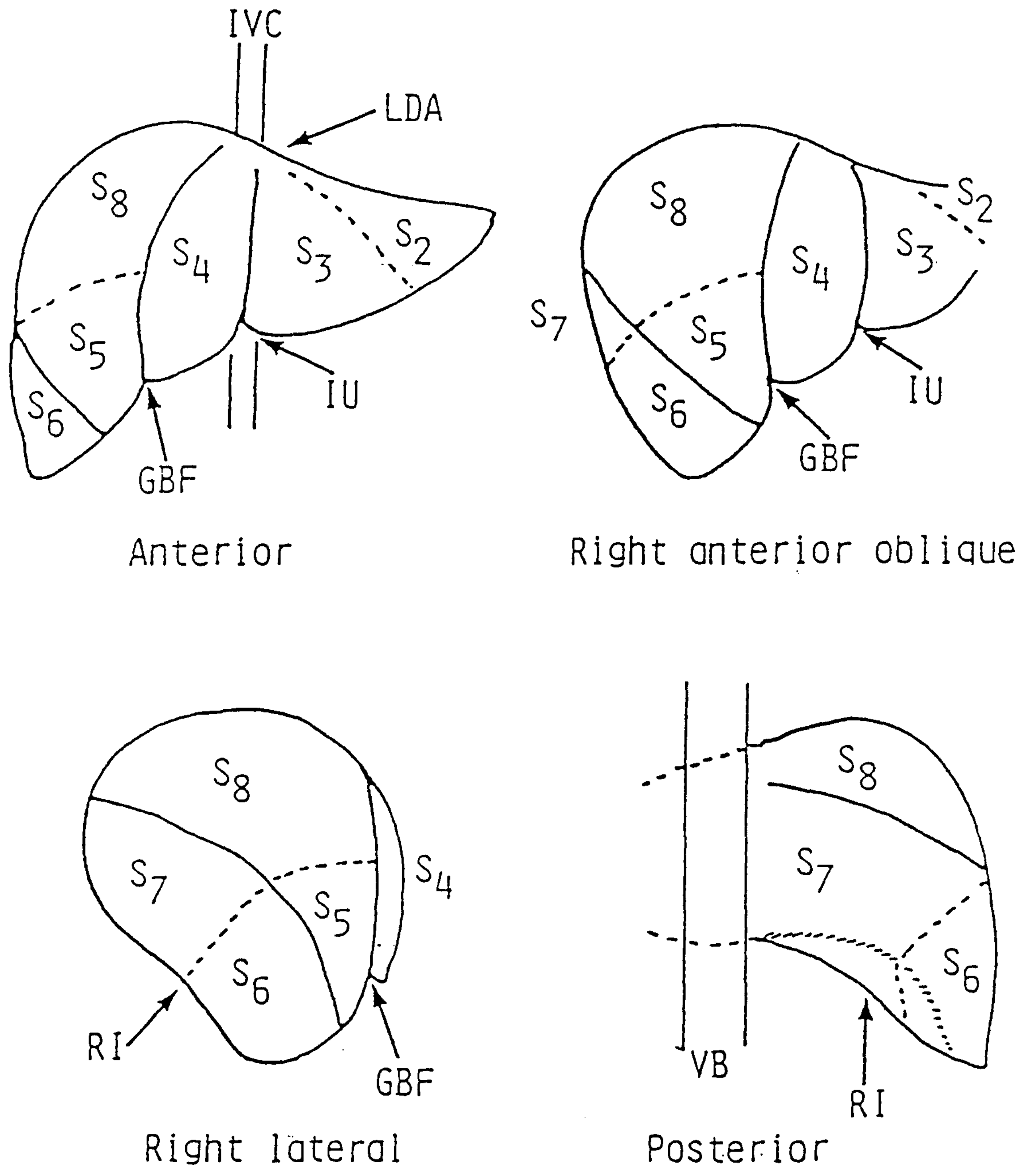
ANALYSIS OF DATA

A data sheet (Appendix A) was completed for every patient and the following information was extracted:-

1. Age and sex of patient.
2. Date and cause of trauma (eg. MVA, assault, etc.)
3. Presenting symptom complex.
4. Physical examination findings.
5. Date and time of Nuclear Medicine scan.
6. Other investigations.
7. Management of the patient.

The exact location of each of the lesions detected on the scans was described according to the segmental anatomy as described by Oyamada, et al. This division of the liver into segments is based on Coinauds segments which are illustrated in Figure 3 (115).

Figure 3: Schematic diagrams of the liver segments on ordinary scintigrams. The caudate lobe (S1) is only identifiable on the transaxial SPECT images. LDA-low density area; GBF-gallbladder fossa; IU-incisura umbilicus; RI-renal indentation; IVC-inferior vena cava; VB-vertebral bodies (from: Oyamada, et al. Segmental assessment on ordinary scintigrams & SPECT images of the liver) (115).



The spleen was arbitrarily divided into upper, middle and lower thirds in order to determine the location of the various lesions seen on the scans.

After the author had analysed the 100 liver-spleen scans in this study, they were independently reviewed by a nuclear physician, who recorded his findings on a data sheet (Appendix B). A second reviewer then looked at those scans where there were discrepancies between the author and the first reviewer and the final diagnosis was made. The final result column (Appendix C) was used for data analysis in all patients in this study.

Using the information extracted from the data sheets, tables were drawn manually depicting the number of patients who met each of the different inclusion criteria and the associated intra and extra-abdominal injuries.

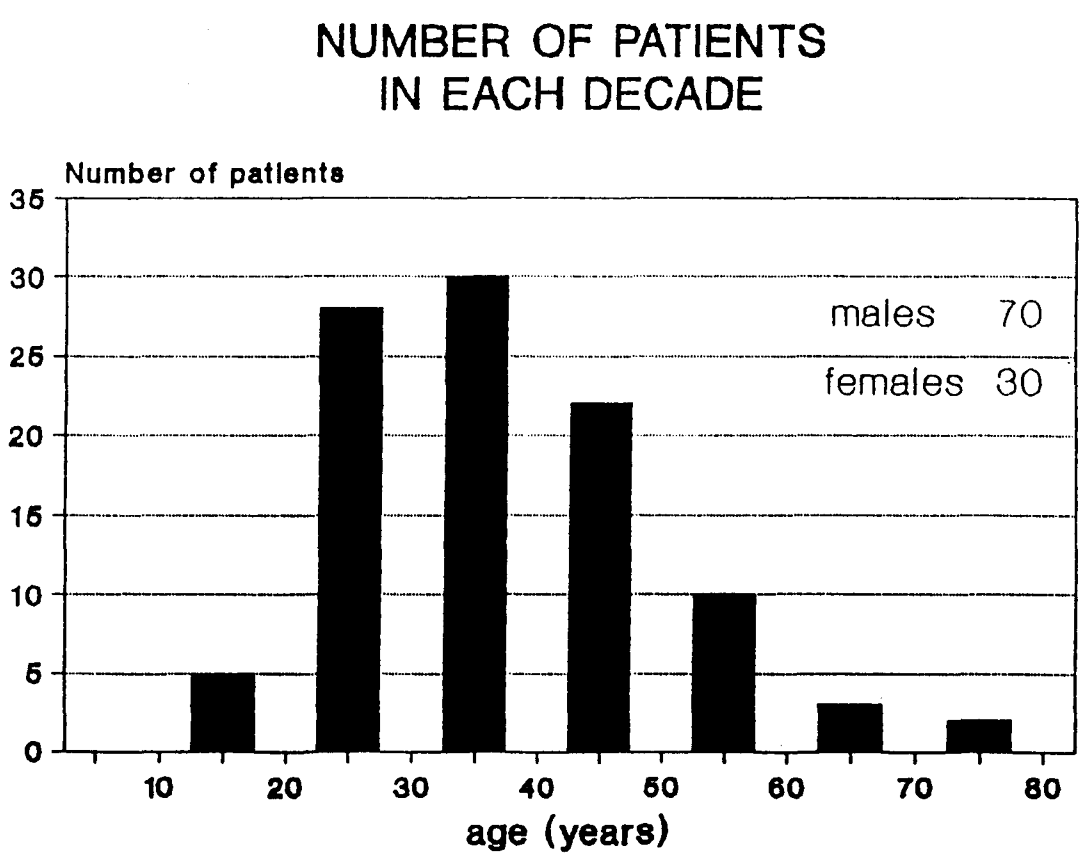
Histograms were drawn using the Harvard Graphics programme depicting the time interval between the traumatic incident versus the time of the liver-spleen scan and the age range of the patients who were scanned.

CHAPTER FOUR : RESULTS

PATIENTS

One hundred consecutive patients with blunt abdominal trauma fulfilling the inclusion criteria were entered into the study. There were 70 males and 30 females with a mean age of 36 years and a range of 15 years to 74 years. The ages of patients are shown in Figure 4. Eighty-five percent of patients were below the age of fifty, and sixty-three percent below the age of forty.

Figure 4 : Histogram showing age distribution of patients



The number of patients admitted for each of the inclusion criteria is listed in table 5. Eighty-seven patients met more than one criterion and 38 patients met more than two criteria for inclusion into this study.

TABLE 5 : Number of patients meeting the individual inclusion criteria

Inclusion criteria	Number of patients
upper abdominal tenderness	64
lower rib fractures (uni/bilateral)	72
unexplained drop in haemoglobin	38
haemoperitoneum on laparoscopy	15
fractured pelvis	13

No patients in this series had diagnostic peritoneal lavage performed.

Mechanism of injury

The commonest mechanism of injury in this series was high speed motor vehicle accidents in 47% of the patients. Fifty-one percent of this group were occupants of the vehicle, either the driver (13 patients) or the front seat passenger (11 patients). This is not surprising as rear-seat occupants of a vehicle are less likely to sustain abdominal trauma because the impact is against the interior of the vehicle causing mainly injuries to the head and neck. The mechanism of injury in all the patients in this study is presented in Table 6.

TABLE 6 : Causes of blunt abdominal trauma

Causes	number of patients	
MOTOR VEHICLE ACCIDENT		47
drivers	13	
passengers	11	
pedestrians	22	
cyclist	1	
BLUNT ASSAULT		38
OTHER CAUSES		15
thrown off moving train	7	
fall from heights (>1,5m)	8	

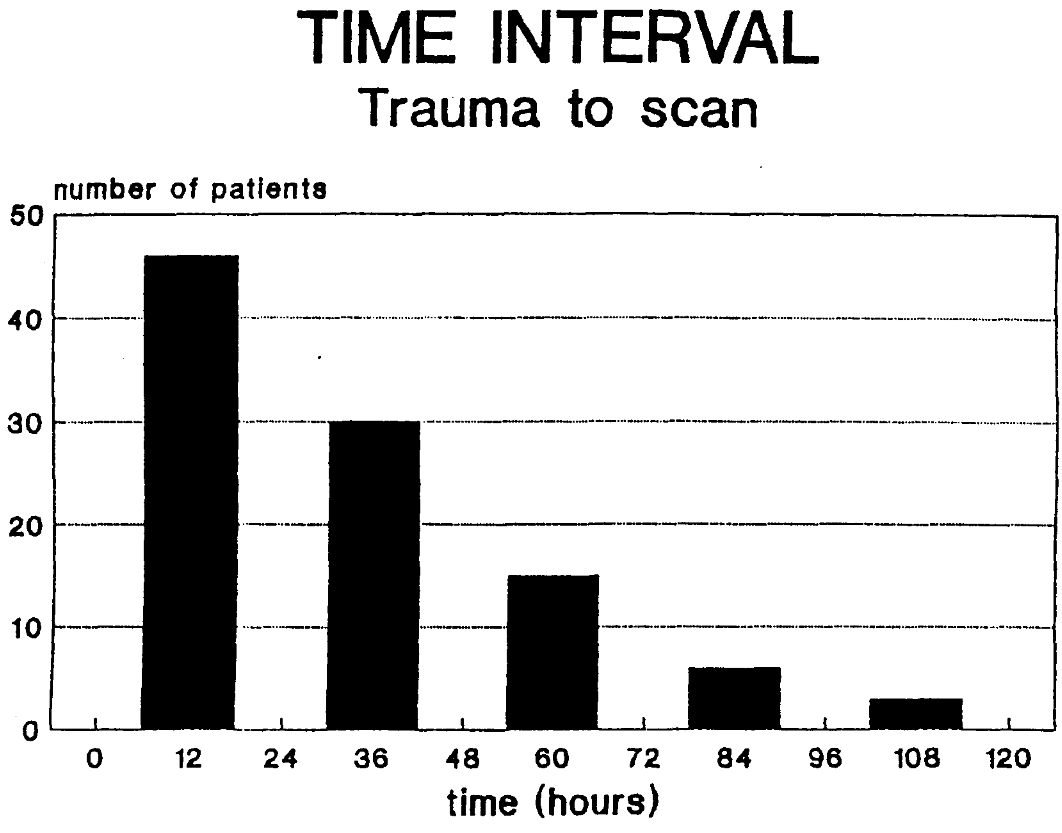
(n = 100)

Interval between trauma and scan

The mean time interval between trauma and the liver-spleen scan was 32 hours with a range of 6 hours to 106 hours. The time interval between the traumatic incident and the scan are shown in Figure 5.

Forty-six patients had a liver spleen scan performed within 24 hours of injury and 91% of the scans were completed within 72 hours of injury.

Figure 5: **Histogram showing interval between trauma & scan**



Associated injuries

The majority of patients had associated intra-abdominal or extra-abdominal injuries. Associated intra-abdominal solid or hollow visceral injuries were present in 12 patients (Table 7). The different extra-abdominal injuries, excluding fractures, sustained by the patients in this study were recorded (Table 8).

TABLE 7: Intra-abdominal injuries (excluding liver & spleen)

Intra-abdominal injuries	number of patients
RENAL INJURIES (contusions, lacerations, avulsion, haematoma, traumatic AVF)	9
Small bowel tear/perforation	2
Pancreatic rupture	1

Of the associated injuries, the kidneys were the commonest organ involved. Of the 9 renal injuries sustained in this group of patients, 4 patients sustained concommitant injuries to the right kidney (detected by either IVP or CT), and the right lobe of the liver (detected by scintigraphy) and in the other 5 patients with renal injuries, no liver or spleen trauma was detected on scintigraphy.

TABLE 8 : Extra-abdominal injuries

Site of injury	*number of patients
Head & neck	40
Chest	55
Limbs (excluding fractures)	10

* 5 patients had injuries to more than one anatomical area

Thirty five of the 100 patients in this study sustained fractures in addition to other injuries and some of these were at multiple sites (Table 9).

TABLE 9 : Associated Fractures

Site of fracture	no. of patients with fractures
skull	12
spine	14
femur	12
humerus	4
radius & ulnar or radius only	8
tibia & fibula or tibia only	11
pelvis	13
sacro-iliac joint	2
ribs	72

The commonest site of fracture, excluding ribs, was found to be in the long bones. In 43 patients there were 148 long bone fractures.

Clinical features

Based on the presence or absence of liver and spleen injuries as seen on liver-spleen scintigraphy the patients were divided into two groups and the clinical presentation analysed. There were 38 patients in the group which had liver or spleen injuries detected on scintigraphy. Of these 30 (79%) were male and 8 (21%) were female.

An analysis of the presenting symptoms of all the patients in this study is shown in table 10 and the physical signs in table 12.

Of the 100 patients in this study, 24 did not complain of pain in the upper abdominal area and physical examination was unhelpful. The indications for liver-spleen scintigraphy in this group of 24 patients, which I have called the 'asymptomatic group', is outlined in Table 11.

TABLE 10 : Symptom complexes

SYMPTOM COMPLEX*		Number of patients L/S injury n = 38	no L/S injury n = 62
Lower chest pain and abdominal pain		8 **(21%)**	18 **(29%)**
Localised abdominal pain	- UPPER	13 **(34%)**	0 **(0%)**
	- RUQ	13 **(34%)**	3 **(5%)**
	- LUQ	13 **(34%)**	6 **(10%)**
	- LOWER	3 **(8%)**	2 **(3%)**
Generalised abdominal pain		5 **(13%)**	5 **(8%)**
Abdominal pain and chest pain on coughing		2 **(5%)**	11 **(18%)**
Only chest pain on coughing		8 **(21%)**	9 **(15%)**

* in 27 patients more than one symptom was found
L/S = liver / spleen
RUQ = right upper quadrant
LUQ = left upper quadrant

Using scintigraphy, 10 patients (42%) of the 'asymptomatic' group were found to have liver or spleen injuries with 8 injuries in the liver and 3 in the spleen. One patient had both liver and spleen injuries.

Table 11 : Inclusion criteria for 'Asymptomatic' group

Indication for scan	patient number	
	with liver spleen injury n = 10	with no injury n = 14
unexplained drop in haemoglobin	5	8
rib fractures	6	9
pelvic fractures	2	0

Diffuse abdominal tenderness was found to be the most significant physical sign indicating injury to the liver or spleen (ie. 32%). All of the other physical signs listed in the table are seen to occur in both groups and were therefore not particularly helpful in deciding if injuries to the liver or spleen were present or not in this series.

Although diffuse abdominal tenderness was found to be the most significant physical sign predicting injury to the liver or spleen, the finding that an unexplained drop in haemoglobin occurred in 50% of patients with proven injury as opposed to 31% without injury must be emphasized.

TABLE 12 : Clinical findings

Clinical findings*	Number of patients L/S injury n = 38	 no L/S injury n = 62
Shock on admission	13 **(34%)**	17 **(27%)**
Lower chest tenderness & bruising	20 **(53%)**	32 **(52%)**
Tender abdomen - upper abdomen	6 **(16%)**	10 **(16%)**
- RUQ only	8 **(21%)**	14 **(23%)**
- LUQ only	10 **(26%)**	16 **(26%)**
- diffuse	12 **(32%)**	11 **(18%)**
- lower	1 **(3%)**	5 **(8%)**
Bruising & abrasions	8 **(21%)**	13 **(21%)**
Guarding	11 **(29%)**	14 **(23%)**
Rebound tenderness	3 **(8%)**	3 **(5%)**
Abdominal distention	4 **(11%)**	12 **(19%)**
Glasgow Coma Scale < 15/15	8 **(21%)**	18 **(29%)**
Macroscopic haematuria	1 **(3%)**	7 **(11%)**
Unexplained drop in haemoglobin	19 **(50%)**	19 **(31%)**

* 12 patients with liver-spleen injuries and 20 with no injuries were found to have more than one physical sign on examination

L/S = liver/spleen
RUQ = right upper quadrant
LUQ = left upper quadrant

CLINICAL GRADING

Prior to scanning patients were arbitrarily graded into two clinical groups depending on the level of suspicion of a liver or spleen injury following clinical examination. Grade 1 patients were those in whom a high index of suspicion existed and grade 2 patients were those clinically assessed as less suspicious and in whom a liver or spleen injury had to be excluded. These two groups of patients were correlated with the presence or absence of a liver or spleen injury as seen on liver spleen scintigraphy. There were 53 patients in grade 1 and 47 patients in grade 2.

TABLE 13 : Correlation between clinical grade and liver spleen injury

Clinical grade		Number ofpatients	
		L/S injury n = 38	no L/S injury n = 62
Grade 1	(53 patients)	26 **(49%)**	27 **(51%)**
Grade 2	(47 patients)	12 **(25%)**	35 **(75%)**

Twenty-one of the 27 patients in group one (high clinical index of suspicion) in whom no liver or spleen injury was detected on scintigraphy had associated injuries which made the clinical assessment difficult. These associated injuries were unilateral lower rib fractures with upper abdominal tenderness (n=10), severe renal injuries (n=9), fractured pelvis (n=5) and bilaterally fractured ribs (n=1).

In the group of patients in whom no liver or splenic injury was detected (n=62) the clinical signs could be accounted for by severe renal injuries in 5 patients, small bowel perforations in 2 patients and a ruptured pancreas in 1 patient. No organ damage was found in the other 54 patients.

Liver-spleen scintigraphy

Liver-spleen scans were acquired, as described in the method (chapter 3), in the 100 patients who were included in this study and the results were analysed. A total of 40 injuries in the liver and spleen were imaged in 38 patients ie. 2 patients had injuries to both the liver and spleen.

TABLE 14 : Injuries detected on liver spleen scintigraphy

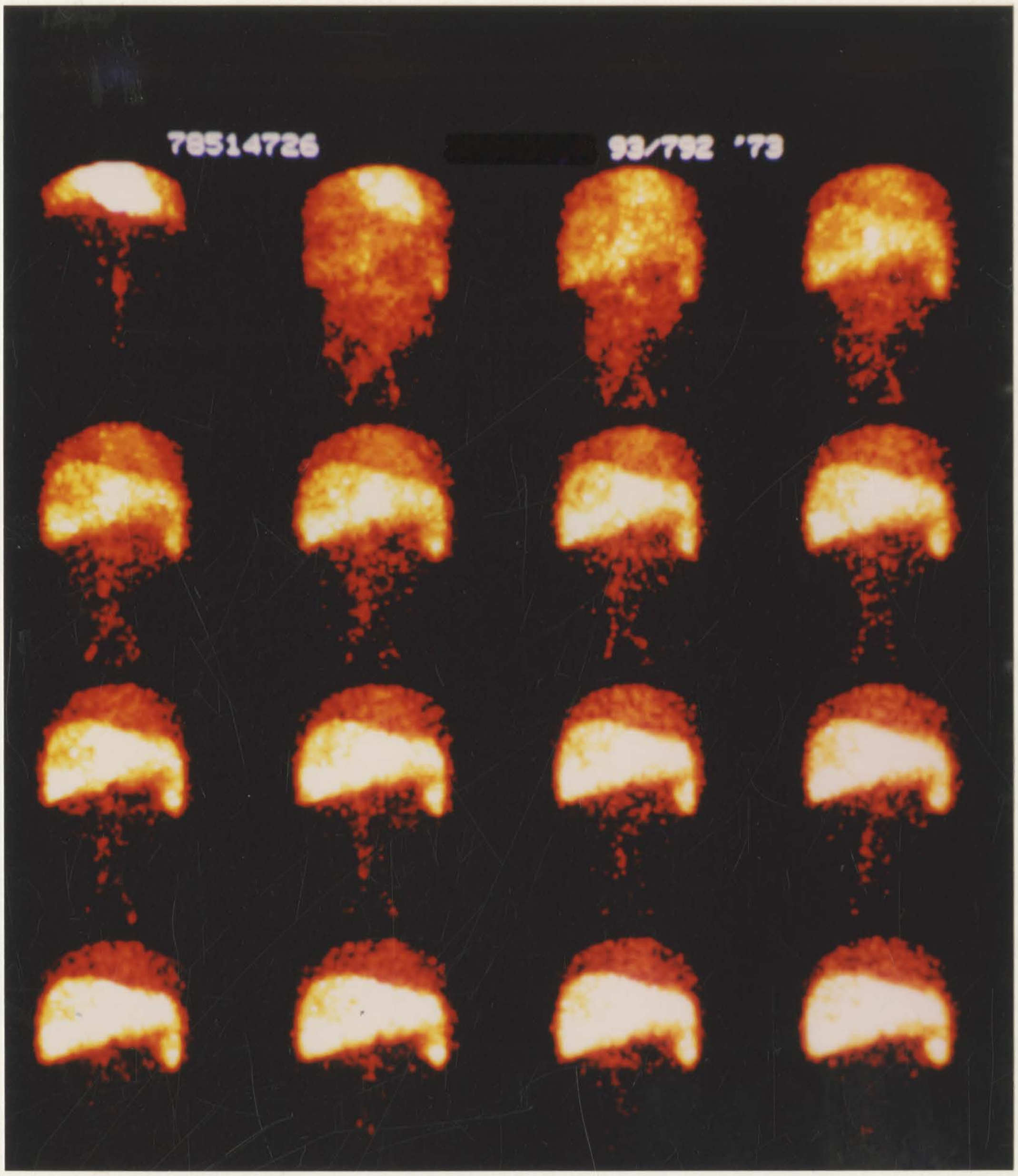
Injury	n = 38
Splenic injury only	9
Liver injury only	27
Liver and spleen injuries	2

Dynamic phase:

Dynamic scans were performed on all patients in this study group and in all 100 studies performed the liver was visualized. The spleen was visualised in 99 patients as one patient had had a previous splenectomy for haematological reasons.

In the 38 patients with liver-spleen injuries, 6 patients had focal areas of reduced perfusion in the liver and 6 patients had either focal or inhomogenous areas of reduced perfusion in the spleen on the dynamic study.

Figure 6: **Dynamic phase of liver-spleen scan with a focal area of reduced perfusion in the dome of the right lobe of the liver.**



Liver injuries

Liver injuries were described as a laceration, haematoma or contusion and an analysis of the findings is described below (Table 15) (Figure 7 & 8).

TABLE 15 : Liver injuries

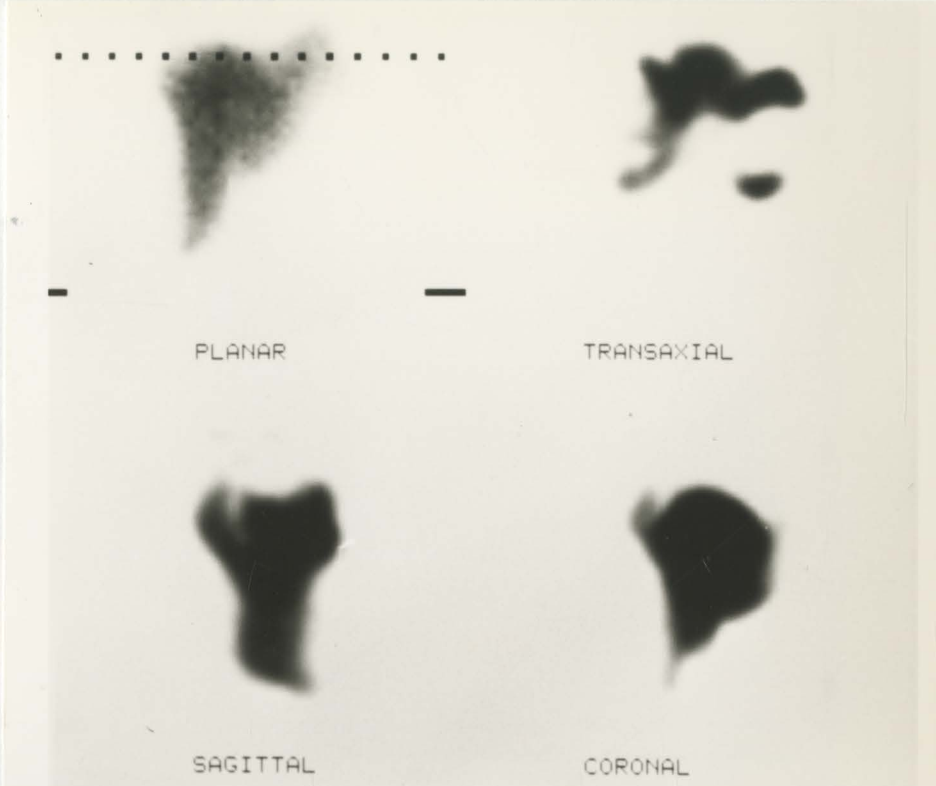
Injuries*	number n = 28
Laceration	8
Haematoma	2
Contusion	10
Laceration and haematoma	6
Contusion and laceration	2

* 2 patients had liver and spleen injuries

A focal area of absent uptake in the liver seen on scintigraphy was subsequently found to be a hydatid cyst on ultrasound examination.

Figure 7: Laceration in dome of the right lobe of the liver as seen on (a) SPECT images and (b) Ultrasound

7(a): SPECT images



7(b): Ultrasound image

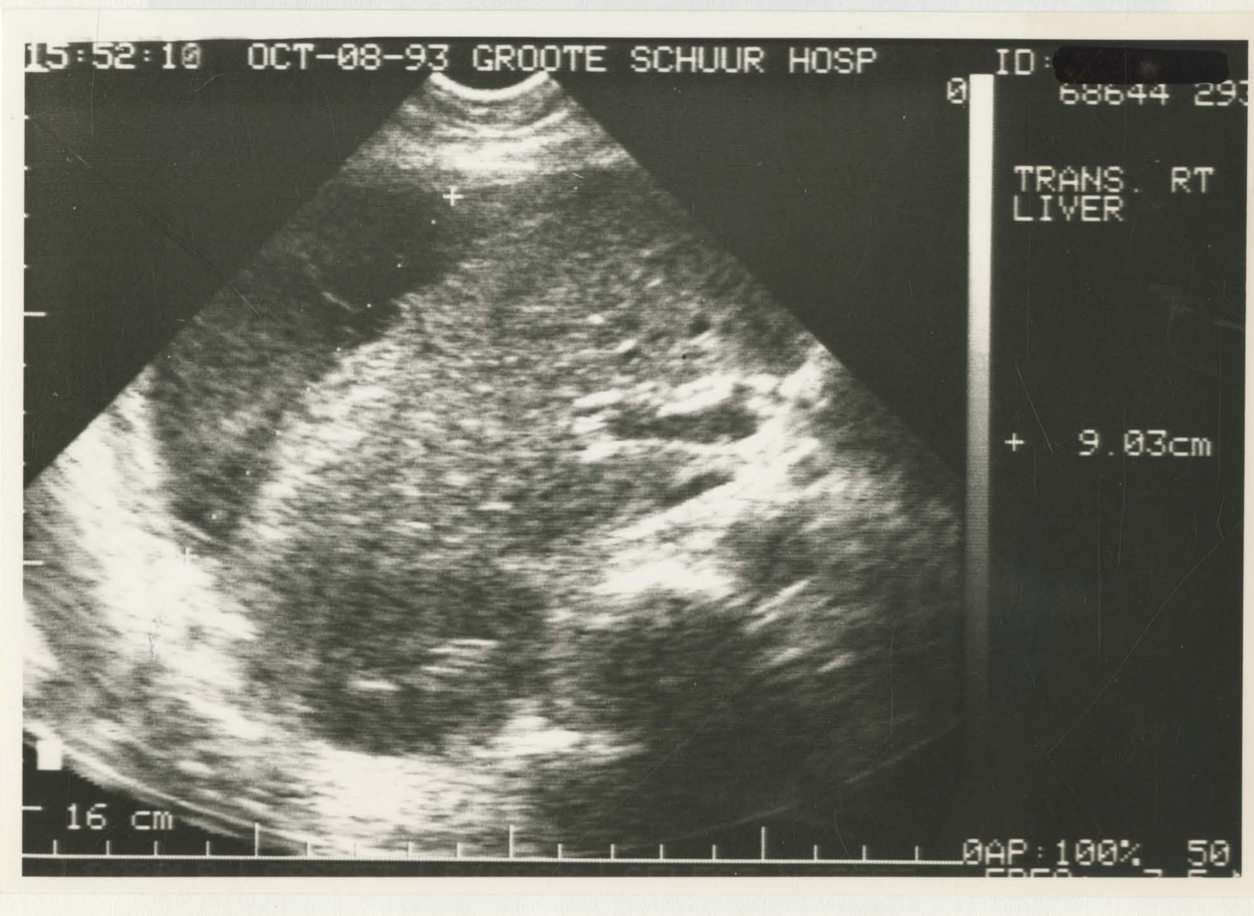


Figure 8: A haematoma in the antero-superior aspect of the right lobe of the liver on (a) SPECT, (b) US and (c) CT scan images.

Figure 8 (a): SPECT images

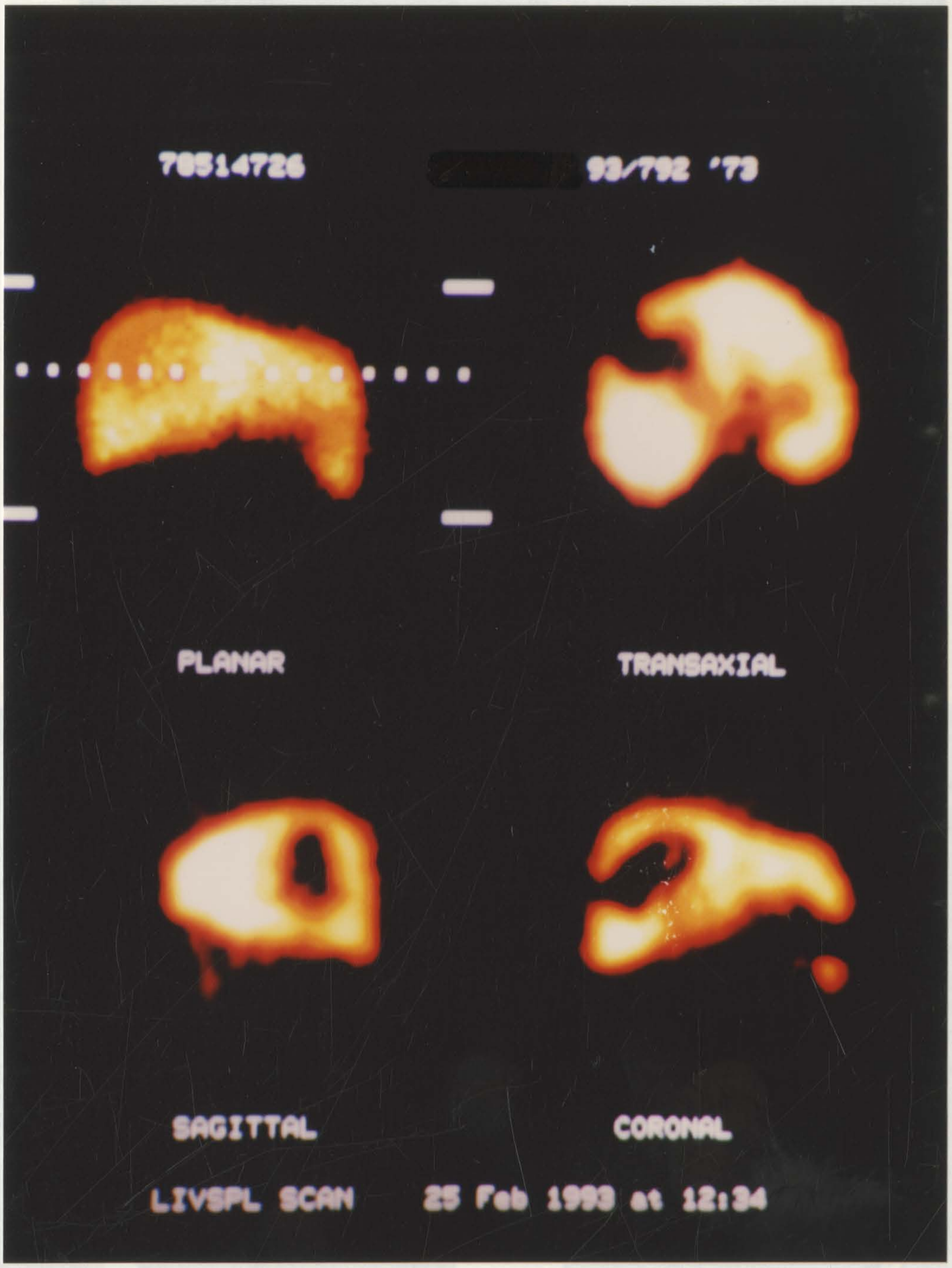


Figure 8 (b): Ultrasound image

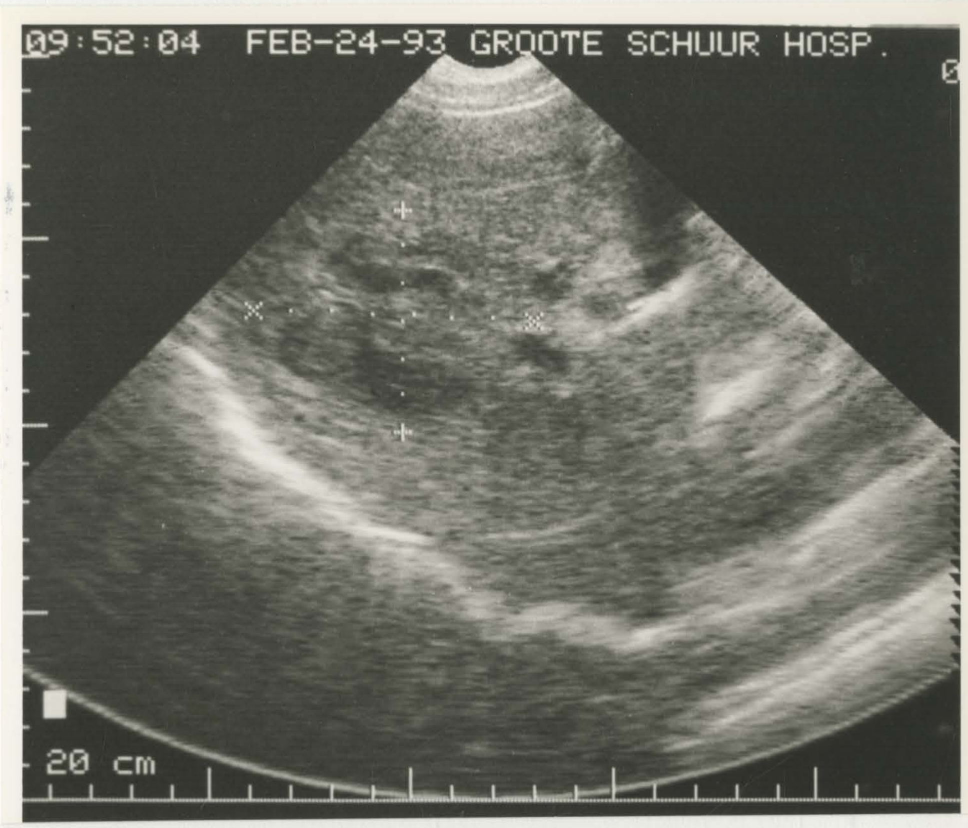


Figure 8 (c): CT scan

The site of liver injury was described according to Coinaud's segments outlined in the method. The number of injuries in each segment was recorded (Table 16).

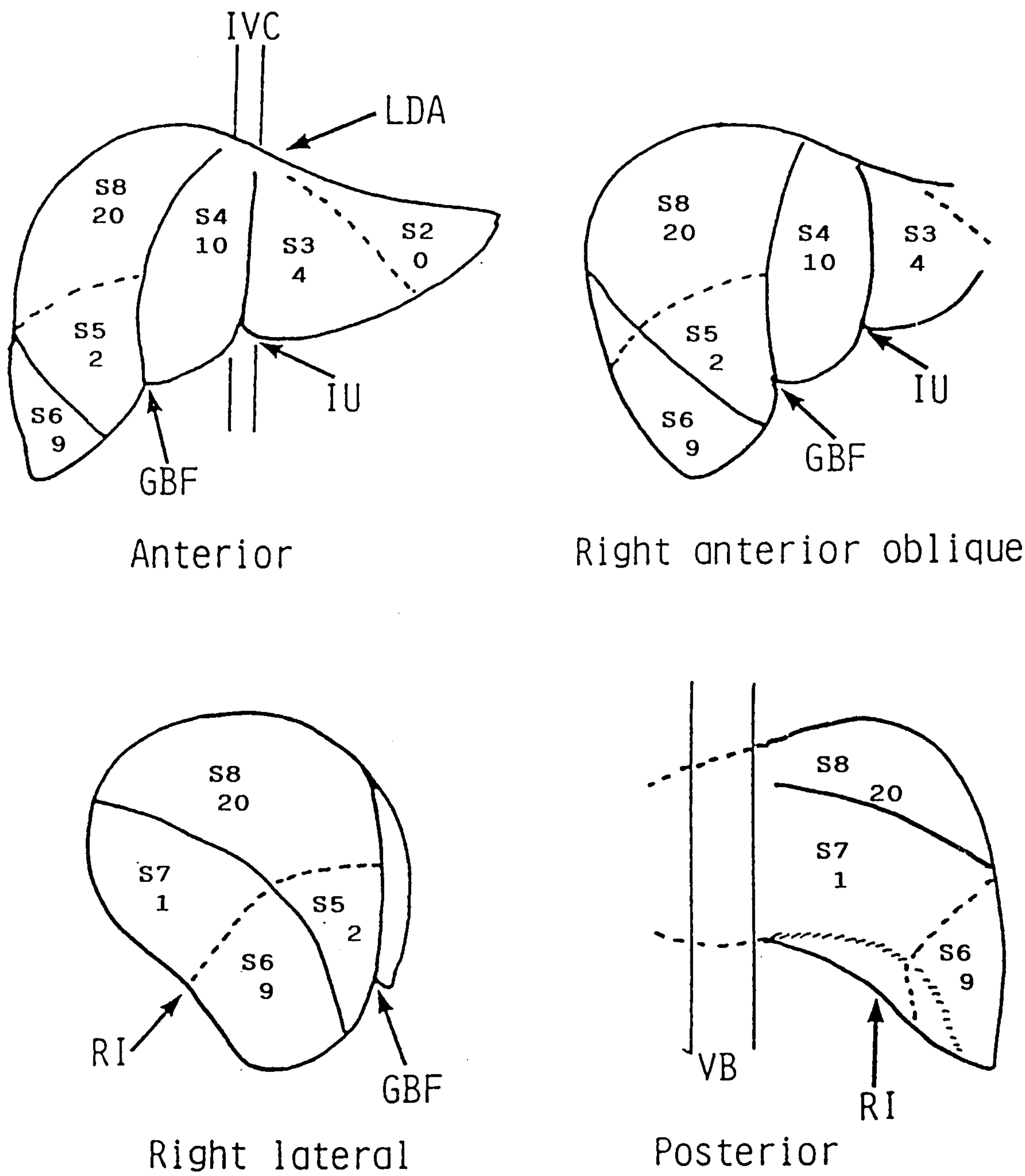
TABLE 16 : Segments involved in liver injury

Segment	no. of injuries per segment*
S1	0
S2	0
S3	4
S4	10
S5	2
S6	9
S7	1
S8	20

* 12 patients were found to have lesions which extended across more than one segment

A schematic diagram illustrating the number of injuries in each segment is seen in Figure 9. The injuries have been grouped together to depict the sites of the lesions rather than the type of lesion.

Figure 9: Segmental distribution of liver injuries in this group of patients (Coinaud's segments)



Spleen Injuries

In the spleen the injuries were described as lacerations, haematomata or contusions, and the numbers of each type of lesion were recorded (Table 17) (Figures 10,11 & 12).

TABLE 17 : Types of Splenic injuries

Splenic injury	n = 12*
LACERATION ONLY	7
HAEMATOMA ONLY	2
LACERATIONS & HAEMATOMATA	2
CONTUSION ONLY	1

* 2 patients had both liver and splenic injuries

The splenic injuries were described according to whether they occured in the upper, mid or lower thirds.

TABLE 18 : Sites of Splenic injury

Site of injury	n = 12*
Upper third	5
Middle third	4
Lower third	3
All three zones	1

* 3 patients had lesions extending over more than one third of the spleen.

Figure 10: A laceration in the postero-superior spleen as seen on (a) SPECT and (b) transverse ultrasound images.

Fig 10(a): SPECT STUDY

Fig 10(b): Transverse ultrasound image

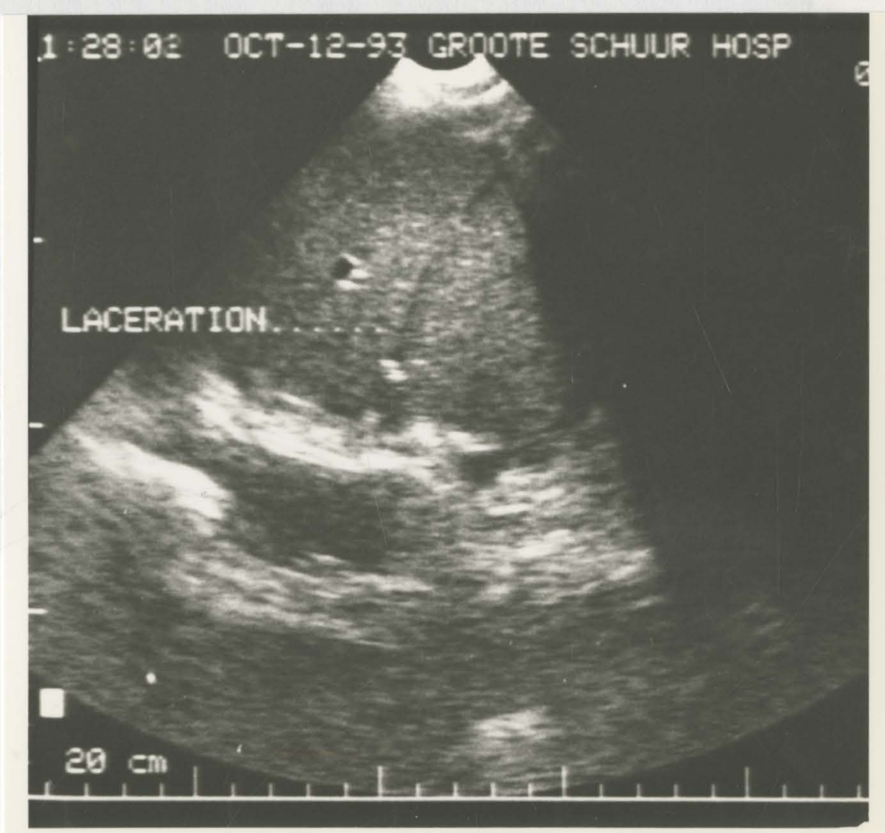


Figure 11: A splenic laceration completely transecting the mid-portion of the spleen on SPECT images.

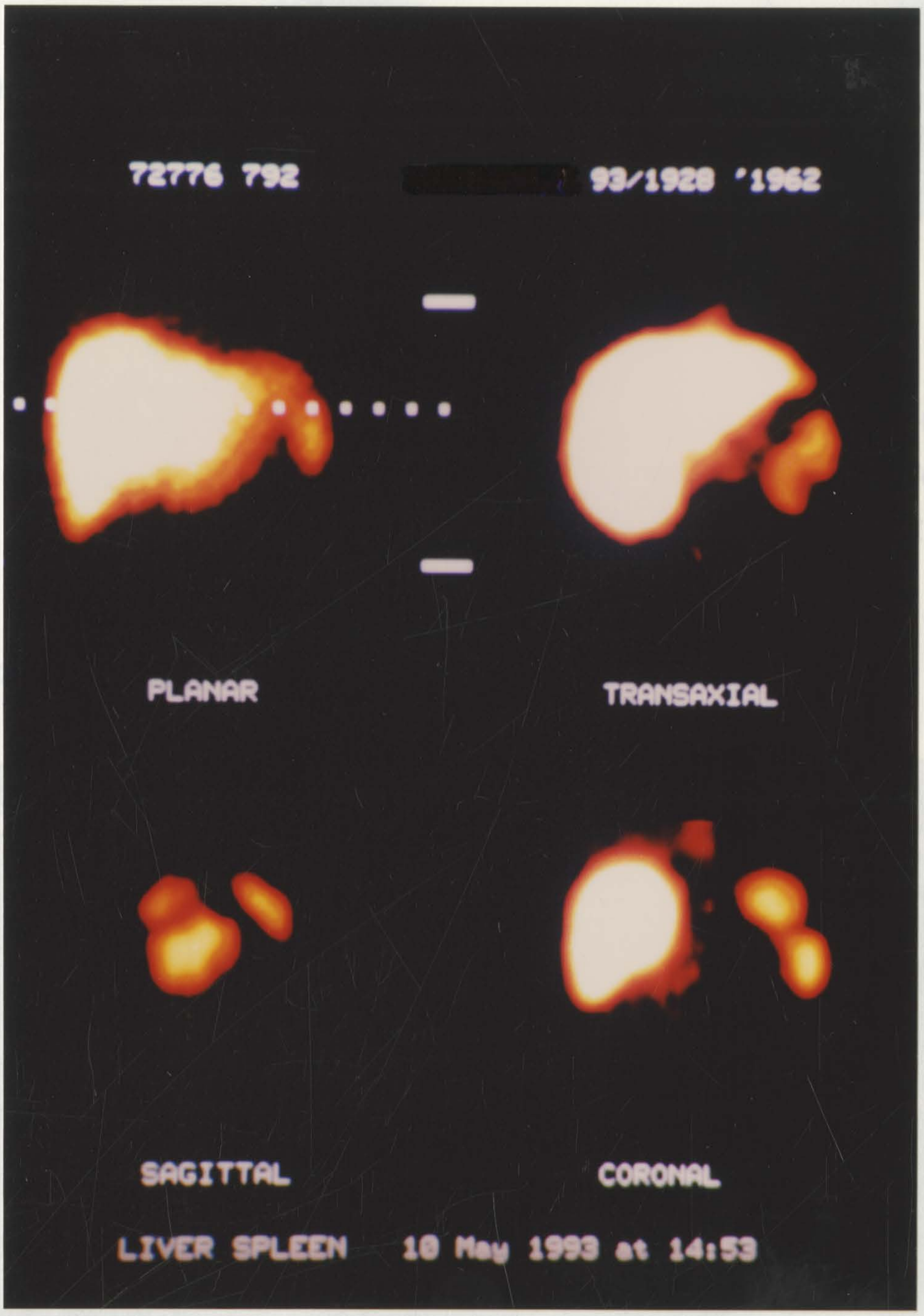


Figure 12: Coronal SPECT images of a massive splenic haematoma at (a) initial presentation and (b) three month follow-up. The longitudinal ultrasound images (c) were taken at the initial presentation.

Fig 12: (a) & (b)

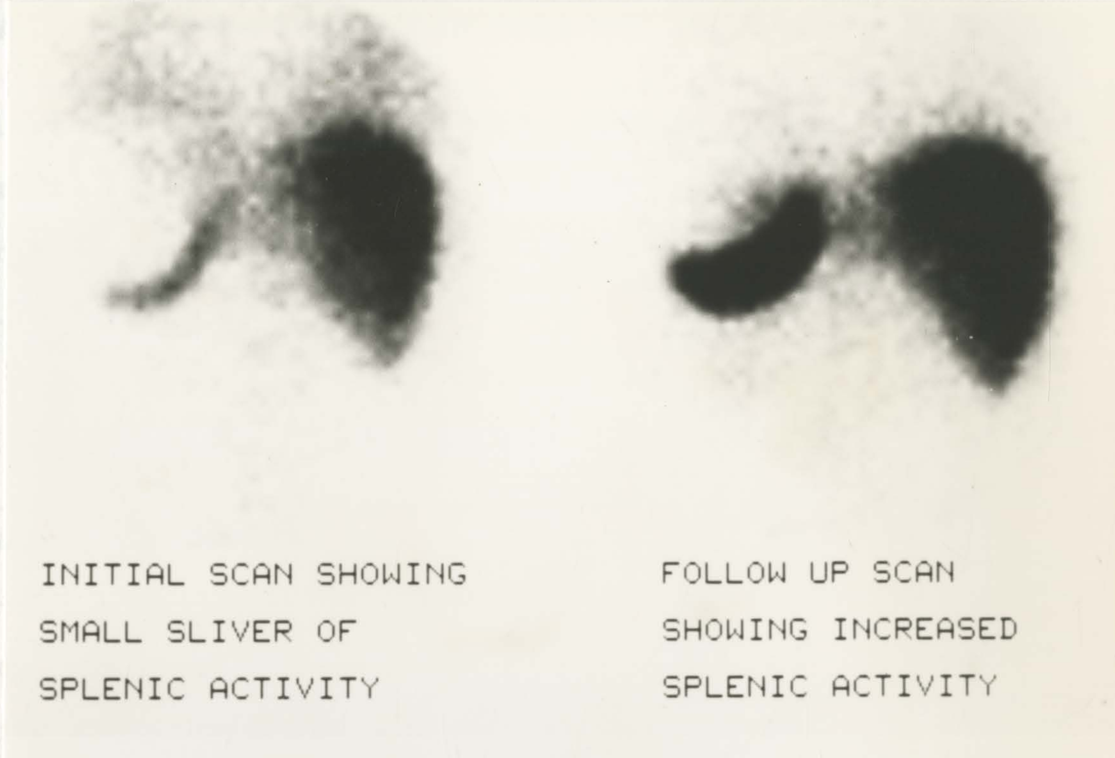
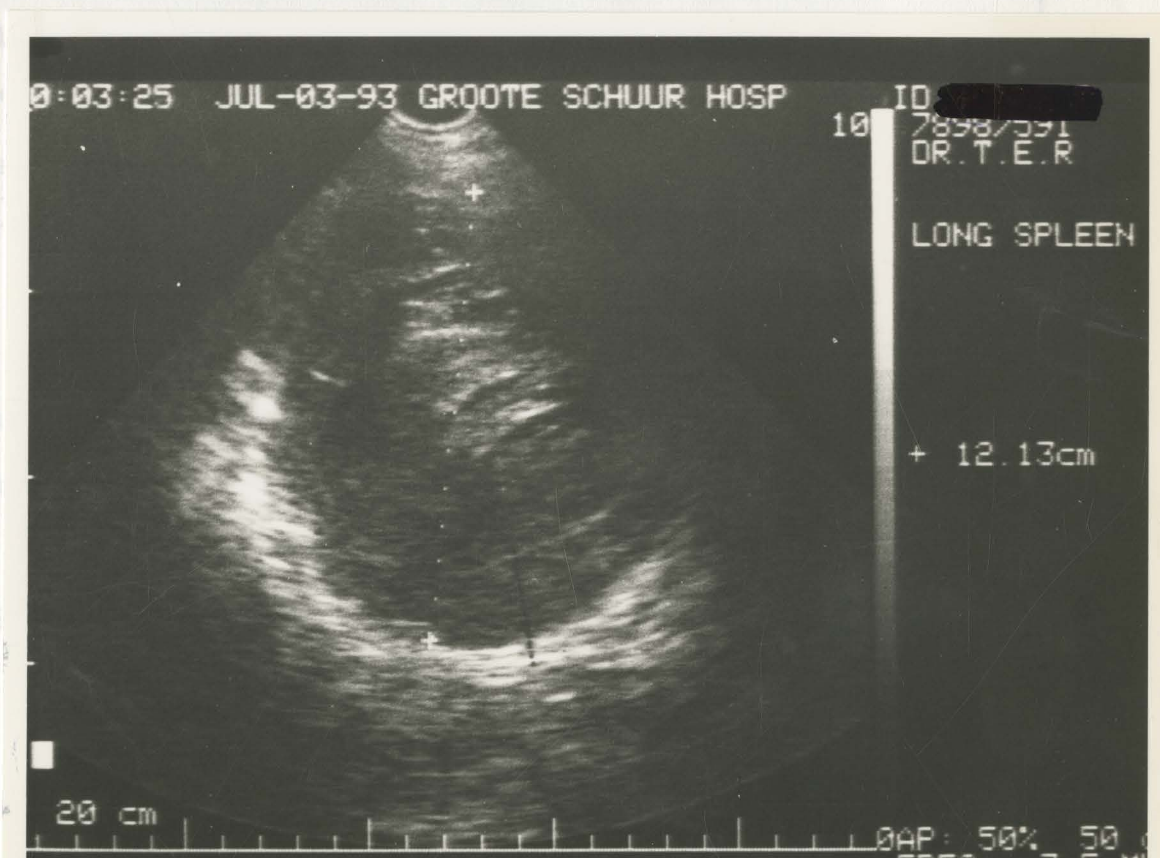


Fig 12 (c):



NORMAL ANATOMICAL VARIANTS OF THE LIVER AND SPLEEN

The liver, more often than the spleen, has several anatomical configurations. The shape of the liver and spleen was analysed in all the patients in this study.(Table 19) (Figure 13)

TABLE 19 : Anatomical variants of the liver

Anatomical variant	no. of variants*
normal wedge shape	40
entire liver enlarged	10
large right lobe	3
Riedels lobe	13
long thin left lobe (over spleen)	9
'gendarme' variant	13
enlarged left lobe - quadrilateral	23

* n = 100

In 40% of patients in this study a normal wedge-shaped liver was seen, whilst in 11 patients more than one variant in liver shape was seen on the liver-spleen scan. In 8 patients an anterior splenic notch was seen and in 7 patients a moderately enlarged spleen was imaged.

In 10 patients, with a history of alcohol abuse, 'colloid shift' was detected indicating some degree of liver dysfunction causing reduced hepatic, but increased splenic uptake.

Figure 13: Normal variants of the liver

Fig 13 (a): Normal wedge-shaped liver

Fig 13 (b):"en chapeau des gendarmes" or "policeman's hat"- normal variant shape of liver

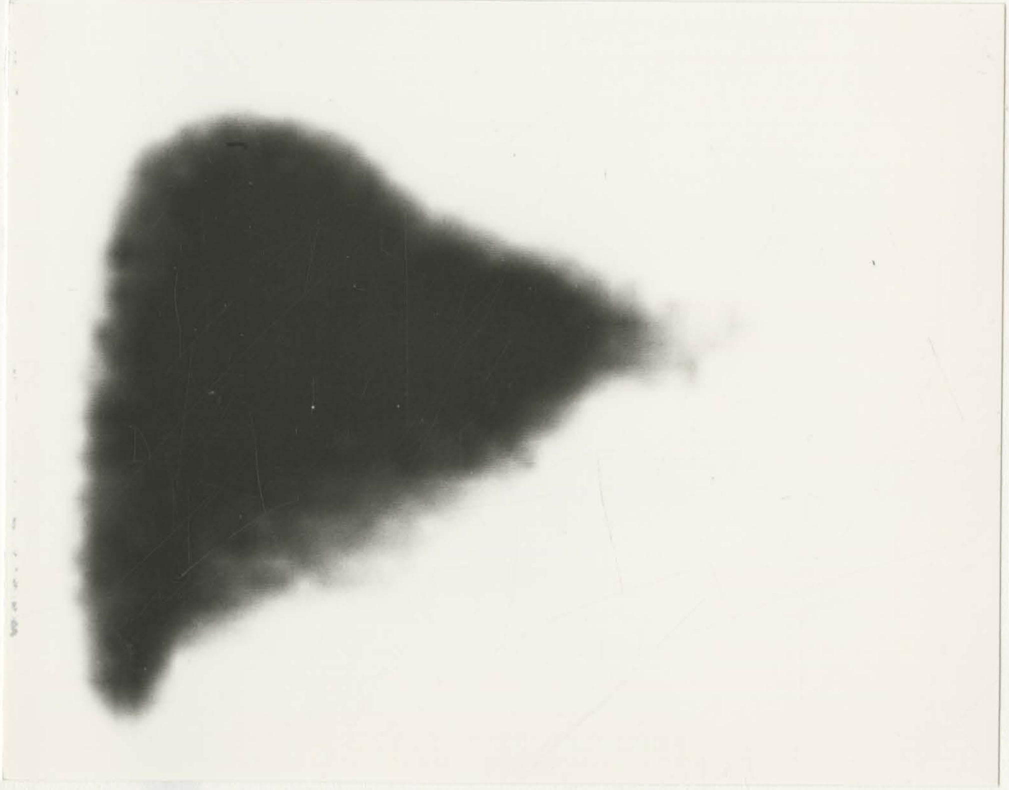


Fig 13 (c): Quadrilateral shaped liver - normal variant

Fig 13 (d): Elongated left lobe of liver - normal variant

Fig 13 (e): Riedels lobe - normal variant of liver.

Normal variant shapes of the liver continued

Fig 13 (f): bulky right hepatic lobe - normal variant.

Fig 13 (g): both right & left lobes bulky - normal variant

Interpretive Difficulties

All 100 patients in this series were initially reported by the author and subsequently reviewed by a nuclear physician (first reviewer) and in 29 cases where discrepancies were found consensus with a second reviewer was reached (Table 20 & 21). In all 29 cases the final result column (Appendix C) was used in the data analysis.

Table 20 : Differences between the authors' report and the consensus view

Pt. no.	Authors' report	Accepted Final Result
21	contusion seen - porta hepatis	Absent
24	liver contusion missed-posterior R lobe	Present
35	haematoma - seen in splenic hilum	Absent
42	inferior splenic laceration missed	Present
43	subcapsular haematoma of spleen seen	Absent
49	missed liver contusion - dome of R lobe	Present
57	liver laceration seen-posterior R lobe	Absent
69	liver laceration seen - dome of R lobe	Absent
73	liver laceration seen-falciform ligament	Absent
77	liver contusion seen - dome of R lobe	Absent
87	no spleen seen	Present
89	missed liver contusion - dome of R lobe	Present
92	liver laceration seen - porta hepatis	Absent

R = right

Table 21 : Differences between first reviewers report and the consensus view

Pt. No.	1st reviewers Report	Accepted Final Result
9	missed liver contusion - falciform ligament/medial left lobe area	present
13	missed liver laceration - dome of R lobe	present
14	missed liver laceration - dome of R lobe	present
21	contusion missed-dome of R lobe of liver	present
32	missed liver contusion - supero-posterior R lobe	present
	missed liver laceration -inferior R lobe	present
38	missed liver contusion - antero-inferior R lobe	present
40	missed liver laceration- dome of R lobe	present
	missed liver haematoma-inferolateral R lobe	present
47	missed spleen laceration - upper third	present
61	missed liver laceration - dome of R lobe	present
62	missed liver laceration- falciform ligament	present
74	missed liver contusion - falciform ligament	present
84	liver laceration seen-mid posterior R lobe	absent
94	missed liver laceration- dome R lobe	present
	missed haematoma - dome R lobe	present

R = right

In 3 patients (numbers 79,87 & 90) the author reported a laceration in the dome of the right lobe of the liver. These were not reported by the first reviewer and the second reviewer was undecided as to whether it was normal or abnormal. These 3 patients were therefore reported as indeterminate studies.

Although there were differences in the scintigraphic findings between the author and the first reviewer in 29 patients, with the second reviewer consensus was obtained in 26 of these patients. In the remaining 3 patients where the second reviewer was undecided, these were reported as indeterminate studies. Thus, of the 100 patients included in this study in only 3 patients could no diagnosis be made.

Other investigations to detect the presence of Liver and Spleen injuries

In 28 patients radiological investigations were done.

TABLE 22 : Other investigations for liver-spleen injury

Ultrasound	14
Computerised tomography	9
Laparoscopy	5

In 11 of the 14 patients who had ultrasound examinations of the upper abdomen the findings correlated with the findings on liver-spleen scintigraphy (Figures 7, 10 & 12). In one patient both scintigraphy and CT (with contrast) detected a subcapsular haematoma of the spleen but US could not locate this lesion.

Of the 9 patients who had CT (with contrast), in 7 of these patients the results confirmed that of liver-spleen scintigraphy (Figures 8 & 11). In the remaining 2 patients scintigraphy showed a massive contusion in one and a minor liver laceration in the other patient. Both of these lesions were not visualized on CT.

Five of the 100 patients in this study had laparoscopy either prior to or following liver-spleen scintigraphy, the findings of which were not known to the author when the liver-spleen scans were interpreted. All 5 patients were found to have free blood in the peritoneal cavity on laparoscopy. Two of these 5 patients had liver or splenic injuries seen on laparoscopy and scintigraphy independently, and 2 patients had small bowel perforations requiring laparotomy. A lesion could not be demonstrated by scintigraphy in 1 patient where free blood was found in the peritoneal cavity.

The following table illustrates other investigations that were carried out in this study group for injuries to organs excluding the liver and spleen.

TABLE 23 : Other investigations

Investigation	no. performed	no. positive
INTRAVENOUS PYELOGRAM	8	7
CT HEAD	9	2
ANGIOGRAPHY	2	1
MYELOGRAM	1	0
BARIUM MEAL	1	0
MRI	0	0

Follow-up Liver Spleen Scintigraphy

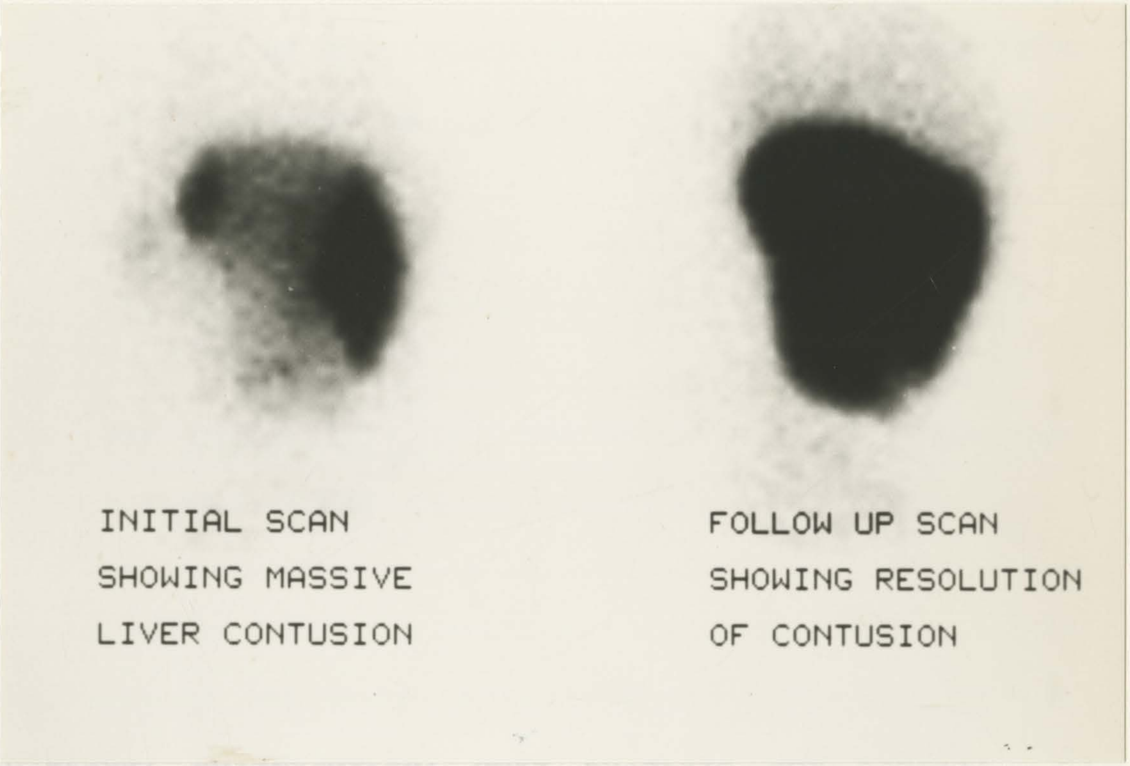
Of the 100 patients, 8 patients had a follow-up scan three months after the traumatic event to assess if there was any resolution of the injury. The results of the follow-up scans are tabulated below (Table 24) and resolution of a hepatic contusion is shown in Figure 14.

TABLE 24 : Results of Follow-up scans

Patient no.	Initial scan findings	Follow-up scan findings
7	minor liver laceration	complete resolution
13	minor laceration & contusion of liver	complete resolution
32	massive liver contusion	almost complete resolution
54	large splenic laceration	almost complete resolution
64	large splenic laceration	complete resolution
73	widened falciform ligament	no change
77	contusion in dome of right lobe of liver	no change
87	splenic contusion	partial resolution

Figure 14: Planar scintigraphy of large contusion in right lobe of the liver at (a) initial presentation and (b) three month follow-up scan showing resolution of the lesion.

(a) (b)



Analysis of the 'Positive group' of patients (n=38)

Of the 38 patients who sustained liver and/or spleen injuries in this series, 9 were female and 29 were male.

The age range of this group (n=38) was found to be 15 to 57 years, with most of the patients in the 20 to 39 year age group.

The mechanisms of injury in this group (n=38) in decreasing order of frequency were found to be assault (11), MVA pedestrian (10), MVA driver (6), MVA passenger (5), fall from height >1m (5) and other causes (1).

All of these patients had other injuries which included fractures of the spine, long bones and clavicle, ligament injuries, pneumothorax, knee injuries and others. No patients had isolated liver or spleen injuries.

No particular physical sign was found to be indicative of a liver-spleen injury.

CHAPTER 5 : DISCUSSION AND CONCLUSION

DISCUSSION

In this dissertation the author has recorded the results of a prospective study that was undertaken to evaluate the role of liver-spleen scintigraphy in blunt abdominal trauma.

An aid to the 'Surgical Dilemma'

Despite the improvements in imaging facilities available, patients presenting with suspected liver or spleen injury following blunt abdominal trauma still pose a challenge to the clinician. This difficulty is often compounded when patients have associated injuries including chest trauma with fractured ribs, and pelvic fractures, as these make the abdominal examination difficult to interpret. In addition, an altered level of consciousness due to an associated head injury or the use of drugs may mask the clinical signs.

Several factors determine the urgency and technique with which blunt abdominal trauma is evaluated. The most important of these is the clinical stability and overall condition of the patient. Criteria have been identified (132) which predict the probability of an intra-abdominal injury requiring prompt abdominal evaluation either by an imaging modality or surgery. Hypotension on admission, an unexplained drop in haemoglobin, major chest trauma and an arterial base deficit have been correlated with major abdominal visceral injury following blunt trauma. Often in this group of patients urgent laparotomy is required and therefore there is no diagnostic dilemma. Sherck, et al. showed, however, that there is no obvious correlation between a lesion seen on CT scan and the need for laparotomy. This is a clinical decision (136).

Findings of this study

In summary, 100 patients had a total of 108 liver-spleen scans, with 8 patients having had follow-up scans.

The author has shown that the adult male group, ranging from 14 to 40 years old is the commonest group to sustain blunt trauma to the abdomen, which confirms other reports (19,20,28,33,34,40,43,161).

As reported by others (28,33,97,129,160) and confirmed in this study, motor vehicle accidents are the commonest cause of blunt abdominal trauma. However, this differs from a recent study in South Africa which recorded interpersonal violence as the commonest cause of blunt abdominal trauma (151).

The commonest indication for including a patient in this study was the presence of lower rib fractures (72% of patients), followed by upper abdominal tenderness. This concurs with other studies in the literature (33). Guarding of the abdomen (52% of patients) and rebound tenderness with rigidity (13% of patients) were found to be less common physical signs in this study group, when compared to reports in the literature, in which these figures are higher (33).

This study confirmed the general experience that the accuracy of abdominal examination following trauma ranges from 50% (17) to 65% (132) because only 57% of patients in this study with a high clinical suspicion of liver or spleen injury were shown to have lesions on scintigraphy. However, 42% of patients who were 'asymptomatic' were found to have lesions in the liver or spleen on scintigraphy. Therefore. clinical examination alone is not sufficient to exclude an intra-abdominal injury.

The author recorded a higher incidence of liver injuries (70%) compared with spleen injuries (30%). The literature is divided on this issue with some studies showing a higher incidence of liver injuries (6,31,47,82) and others a predominance of splenic injuries (2,24,25,97,116,135,160). In those studies that show splenic injuries to be more common than liver injuries scintigraphy was not used for imaging.A higher incidence of liver injuries is supported by a review of 127 motor vehicle accident autopsies which revealed the commonest injury to be liver lacerations (50% of the fatalities) (104).

By dividing the liver into segments, as described by Oyamadu, et al. (115) the author was able to establish that the antero-superior (dome) aspect of the right lobe of the liver was the commonest site of injury followed by the medial segment of the left lobe of the liver. This concurs with other studies (43,44,65,104,115,137) which have postulated that the most likely reason for this is a crushing force to the anterior abdominal wall.

In my study 5% of patients with injury to the liver were found to have associated right renal damage. Renal trauma was indicated by the presence of macroscopic haematuria and confirmed on IVP or CT examination. Based on clinical assessment only, it is often difficult to separate liver and spleen injuries from renal injuries. This may be due to the close proximity of the liver and spleen to the kidneys in the upper abdomen and retroperitoneum respectively. In the presence of a confirmed renal injury an associated liver or spleen injury can be detected using liver-spleen scintigraphy. Although the author confirmed the association of right renal injuries with liver injuries, its occurrence in this study is less than other reports in the literature which range from 13% (33) to 27% (2) in adults.

The management of one patient (1%) in this study group was altered by the findings of liver-spleen scintigraphy. A liver-spleen scan done 8 hours after injury showed a laceration transecting the spleen. The initial decision of the clinician to observe the patient was reviewed when the patient showed signs of haemodynamic decompensation 48 hours later. In view of the scan findings the most likely diagnosis was a laceration of the spleen involving the vascular pedicle. This was confirmed at laparotomy and a splenectomy was performed. This case illustrates several important points - firstly, taking the precaution of admitting and observing patients with suspected liver or spleen injury for delayed rupture and haemorrhage from both the liver and the spleen is justified; secondly, the need for serial abdominal examinations by the clinician; and thirdly the need for an accurate imaging modality which can detect an injury early in the acutely traumatized patient. This patient may well have been sent home if the attending doctors had not been aware of the splenic injury detected by liver-spleen scintigraphy.

A review of the literature has shown a range of 34% (59) to 40% (55) of positive liver or spleen injuries in scintigraphic studies in blunt abdominal trauma. This has been confirmed in this study where 38% positive cases have been demonstrated.

Contribution of Liver-Spleen Scintigraphy

In many medical centres radionuclide scanning has been replaced by newer, more expensive technologies, despite the fact that scintigraphy remains a useful tool in several specific clinical situations and is now widely available (79,63,125). As stated by Oratz, et al (114) none of the imaging modalities, including MRI, can define with certainty the pathogenesis of a space-occupying lesion which is visualized.

Scintigrams reflect the pathophysiological status of the organs of interest, yielding important information which cannot be obtained by CT or US (28). As indicated by other reviews reduced perfusion seen on the dynamic study indicates vascular compromise to that area and this was confirmed in 12% of the patients in this study group.

Another aspect which was confirmed in this study and where scintigraphy specifically contributes to the management of an acutely traumatized patient is in its ability to detect a contusion. Radionuclide imaging is more sensitive than CT in detecting a contusion in an organ. CT cannot delineate a contusion accurately (6) because there is minimal change in tissue attenuation densities between a contusion and the surrounding parenchyma. A contusion represents an area of altered function and is therefore easily detected on liver-spleen scintigraphy as a focus of reduced uptake. A focus of reduced uptake must be differentiated from a "cold" or photopaenic focus which in the acutely traumatized patient maybe due to a haematoma. The presence of a contusion may explain the severe pain experienced by a patient who is otherwise stable and will therefore require no surgical intervention.

If diagnostic peritoneal lavage or laparoscopy detect intra-abdominal blood or blood-stained fluid and liver-spleen scintigraphy shows a laceration of the liver or spleen, then this is the most likely source of the bleeding and unless clinically indicated no further investigations are necessary. Blood or fluid in the abdominal cavity will reabsorb with no complications as long as it remains sterile (3).

Laparotomy is regarded as the "gold standard" because all imaging modalities have different limitations. As confirmatory laparotomies were not performed on all patients in this series comparisons cannot be drawn regarding specificity, sensitivity and accuracy of liver-spleen scintigraphy. However there are sufficient studies in the literature to confirm the diagnostic accuracy of liver-spleen scintigraphy and the benefit of this imaging modality in providing a functional and anatomical study to confirm or exclude the presence of damage to the liver and spleen (6,9,30,31,55,59,67,77,78,79,80,81,85,87,91,92,97, 109,119).

As reported by others (26,42,57,58,67,119) and confirmed by the author, liver-spleen scintigraphy also plays a useful role in documenting resolution of the initial traumatic lesions (Table 24).

Difficulties in Interpretation

Sty (145) has stated that normal variations are one of the most difficult problems in image interpretation. Several anatomical variations of the liver may occur (21,72,108) making the assessment of the liver scan difficult as these may be misinterpreted as pathological. The nuclear physician should therefore have a thorough knowledge of these variations. As found in this study there are inevitably cases which will be catergorized as indeterminate.

Normal liver-spleen scans seem to provide minimal difficulty in interpretation, whilst abnormal scans cause somewhat of a 'dilemma'. Some of the reasons for this include 'over-interpretation', 'under-interpretation', inexperience, excessive emphasis placed on normal variants and inter-observer variability.

The interpretation of liver injuries appears to pose a greater problem than splenic lesions. The right lobe of the liver proved to be the most difficult area (12%) in this study and this is supported by the literature (59). Possible reasons for this are the presence of an overhanging breast or lower rib markings which cause attenuation of photons creating artefacts in the right lobe of the liver. However, with SPECT imaging, these artefacts will only be seen in one plane.

Another pitfall in the right lobe of the liver is the presence of Liebermeister's grooves which occur in 10% of normal livers. These grooves are seen in all three orthogonal planes in the SPECT images making its differentiation from a laceration difficult. CT and US may not be able to distinguish between them and laparotomy, the final arbiter, cannot be performed unless clinically indicated. However, if a defect is seen on the scan attention to details such as the direction, the number and the length of the lesion may be helpful in separating normal variants from true defects.

The second 'problem area' in interpretation was the central area of the liver including the falciform ligament, porta hepatis and medial aspect of the left lobe of the liver. This area is well documented by other authors as a difficult area to interpret (21,22,98,127). A possible reason for this is that the bulky right lobe of the liver changes to a thinner left lobe, divided by the falciform ligament and porta hepatis which themselves are then imaged as areas of reduced uptake. In addition, trauma is known to occur in vascular and ligamentous planes more often than in the parenchyma, particularly as these are points of attachment to the body cavity and therefore provide a plane for shearing.

CONCLUSION

In conclusion, each patient should be evaluated individually as to which is the most appropriate imaging modality. Where there is a high clinical suspicion of a liver-spleen injury, and provided the patient is stable, scintigraphy is the investigation of choice to exclude significant injury of these organs. If the patient has an associated head or retroperitoneal injury then CT is the preferred investigation as both the abdomen and the head can be imaged at the same sitting. Moreover, CT provides a pan-abdominal scan which will detect any retroperitoneal injuries.

From reviewing the literature liver-spleen scintigraphy is a well established imaging modality and supportive or confirmatory evidence by other imaging modalities is not always necessary. There is no doubt that at present the full potential of scintigraphy is not being realized and this maybe due to the problems experienced with interpretation of scans. The importance of visualizing abnormalities in two projections has become axiomatic in both Radiology and Nuclear Medicine. If this principle is adhered to it will reduce some of the potential sources of error in interpretation.

Liver-spleen scintigraphy using SPECT technology is a safe, accurate and cost-effective imaging modality which can be used effectively by the traumatologist when faced with a patient with blunt abdominal trauma and deceptive clinical findings. Certainly a normal scan can give great confidence that all is well with the liver and spleen.

The incidence of liver-spleen trauma in this group of patients was found to be 38% and therefore liver-spleen scintigraphy is of benefit in the patient who has sustained blunt trauma to the abdomen, as a screening procedure or to localize and determine the extent of hepatic and splenic injury.

REFERENCES

1. Aidonopoulos AP, Papavramidis ST, Goutzamanis GD, Filos GG, Deligiannidis NP, Hanos GM. A simple and safe method for preservation of the injured spleen. Injury 1993;24:300-302.

2. Aldrete JS, Halpern NB, Sherri Ward SA, Wright JO. Factors determining the mortality and morbidity in hepatic injuries. Ann Surg 1979;189:466-474.

3. Andersson R, Bengmark S. Conservative Treatment of liver Trauma. World J Surg 1990;14:483-486.

4. Armas RR. Clinical studies with spleen specific radiolabelled agents. Semin Nucl Med 1985;15:260-275.

5. Bailey H & Love M. Short Practice of Surgery. 21st ed. London: Chapman & Hall Medical, 1992.

6. Bass DH, Mann MD, Cremin BJ, Cywes F. A Comparison between Scintigraphy and CT in Blunt Liver & Spleen Injuries in Children. Pediatr Surg Intl 1990;5:443-445.

7. Beal SL. Fatal hepatic haemorrhage. J Trauma 1990;30: 163-169.

8. Bekerman C, Gottschalk A. Diagnostic Significance of relative uptake of Liver compared with Spleen in ^{99m}Tc-Sulfur Colloid Scintigraphy.J Nucl Med 1970;12:237-240.

9. Berg BC. Complementary Roles of Radionuclide and CT Imaging in Evaluating Trauma. Semin Nucl Med 1983;13: 86-103

10. Biello DR, Levitt RG, Siegel BA, Sagel SS, Stanley RJ. CT & Radionuclide imaging of liver. Radiology 1978;127:159-163.

11. Biersack HJ, Reichmann K, Reske SN,Knopp R, Winkler C. Improvement of Scintigraphic liver imaging by SPECT-a review of 797 cases. J Nucl Med 1983;24:29.

12. Bode PJ, Niezen RA, van Vugt AB, Schipper J. Abdominal US as a Reliable indicator for Conclusive Laparotomy in Blunt Abdominal Trauma. J Trauma 1993;34:27-31.

13. Brendel A, Leccia F, Drouillard J, San Galli F, Eresue J, Wynchank S. SPECT, planar scintigraphy and CT. Radiology 1984;153:527-532.

14. Bryan PJ, Dinn WM, Grossman ZD, Wistow BW, McAfee JG, Kieffer SA. Correlation of CT, US and radionuclide imaging of the liver in detecting space-occupying processes. Radiology 1977;124:387-393.

15. Buell U, Kessler M, Kirsch CM, Roedler HV. SPECT for assessment of hepatic lesions. J Nucl Med 1983;24:746.

16. Burnett David A. Rational Uses of Hepatic Imaging Modalities. Semin Liver Dis 1989;9:1-6.

17. Buss CS, Theron EJ, Nel CJC, Monk EJ, De Wet JI. Diagnosis of Abdominal Injuries in Comatose Patients. S Afr J Surg 1990;28:137-140.

18. Butterworth JF, Miller DJ, Maull KI, Becker DP. Detection of Occult Abdominal Trauma in Patients with Severe Head Injuries. Lancet 1980;2:759-762.

19. Calne RY, Wells FC, Forty J. 26 cases of Liver Trauma. Br J Surg 1982:69:365-368.

20. Carmona R, Lim R, Clark G. Morbidity and mortality in hepatic trauma. Am J Surg 1982;144:88-93.

21. Carrasquillo JA, Rogers JV, Williams DL, Shuman WP, Olson DO, Larson SM. SPECT of Normal Liver. AJR 1983;141: 937-941.

22. Carrasquillo JA, Rogers JV, Schuman WP, Olson DO, Williams DL, Larson SM, et al. Hepatic and Splenic Anatomy on SPECT.J Nucl Med 1983;23:44 (abstract).

23. Chambers JA, Ratcliffe JF, Doig CM. US in Abdominal Injury In Children. Injury 1986;17:399-403.

24. Chappell JS . Blunt Abdominal Trauma in Children. S Afr J Hospital Med 1981;7(6):99-105.

25. Chappell JS. Splenic Preservation. S Afr Med J 1984;65:12-14.

26. Cheatam JE, Smith EI, Tunell WP, Elkins RC. Nonoperative management of subcapsular haematoma's of the liver. Am J Surg 1980;140:852-857.

27. Cook DE, Walsh JW, Whitley C, Brewer WH. Upper Abdominal Trauma:Pitfalls in CT Diagnosis. Radiology 1986;159: 65-69.

28. Cox EF, Flancbaum L, Dauterive AH, Paulson RL. Blunt trauma to the liver. Ann Surg 1988;207:126-134.

29. Croll MN. Historic Perspective. Semin Nucl Med 1994;24: 3-16.

30. Cywes S, Rode H, Millar AJW. Blunt Liver Trauma in Children. J Pediatr Surg 1985;20:14-18.

31. Cywes S, Bass DH, Millar AJW. Blunt liver trauma in children. Injury 1991;22(4):310-315.

32. Dauterive AH, Flancbaum L, Cox EF. Blunt Intestinal Trauma. Ann Surg 1985;201:198-203.

33. Davis JJ, Cohn I, Nance FC. Diagnosis and Management of Blunt Abdominal Trauma. Ann Surg 1976;183:672-678.

34. Defore WW, Mattox Kl, Jordan GB. Management of 1590 Cases of Liver Trauma. Arch Surg 1976;111:493-497.

35. Demetriades D. Blunt & Penetrating Abdominal Trauma. S Afr J Continuing Medical Education 1988;6:21-29.

36. Demetriades D, Sofianos C. Penetrating trauma audit - TRISS analysis. S Afr J Surg 1992;30:142-144.

37. DeNardo GL, Stadalnik RC, DeNardo SJ, Raventos A. Hepatic Scintiangiographic Patterns. Radiology 1974;111:135-141.

38. Dendy PP, Gemmell HG. An evaluation of contribution of SPECT to radionuclide imaging of liver. Ann Radiol 1993;26:72-81.

39. Dent DM, Van der Spuy JW. The GP and Abdominal Injury. S Afr Med J 1978;53:290-293.

40. DiVincenti FC, Rives JD, Laborde EJ, et al. Blunt Abdominal Trauma. J Trauma 1968;8:1004-1010.

41. Drum DE, Christocopoulos JS . Hepatic scintigraphy in clinical decision making. J Nucl Med 1972;13:908-915.

42. Evans GW, Curtin FG, McCarthy HF, Kieran JH. Scintigraphy in Traumatic lesions of Liver and Spleen. JAMA 1972;222: 665-667.

43. Farnell MB, Spencer MP, Thompson E, Williams HJ, Mucha P, Ilstrup DM. Non-operative management of blunt hepatic trauma in adults. Surgery 1988;104:748-756

44. Federico JA, Horner WR, Clark DE, Isler RJ. Blunt hepatic trauma non operative management in adults. Arch Surg 1990;125:905-909.

45. Federle MP, Crass RA, Brooke Jeffrey R, Trunkey DD. CT in Blunt Abdominal Trauma. Arch Surg 1982;117:645-650.

46. Feins NR. Multiple Trauma. Pediatr Clin North Am 1979;26:759-771.

47. Feliciano DV, Jordan G, Bitondo C, Mattox KL, Burch JM, Cruse PA. Management of 1000 consecutive cases of hepatic trauma. Ann Surg 1986;204:438-443.

48. Feliciano PD, Mullins RJ, Trunkey DD, Crass RA, Beck JR, Helfand M. A Decision Analysis of Traumatic Splenic Injuries. J Trauma 1992;33:340-347.

49. Filiatrault D, Longpre D, Patriquin H, Perreault G, Grignon A, Pronovost J. Investigation of childhood trauma. Pediatr Radiol 1987;17:373-379.

50. Fischer KC, Eraklis A, Rossello P, Treves S. Scintigraphy in the follow Up Of Paediatric Splenic Trauma Treated Without Surgery. J Nucl Med 1978;19:3-9.

51. Fischer RP, Crotchett PM, Reed RL. GIT Disruption: Hazard of Non-operative Management in Adults with Blunt Abdominal Injury. J Trauma 1988;28:1445-1449

52. Fleming JS, Ackery DM, Walmsley BH. Scintigraphic estimation of arterial and portal blood supplies to the liver. J Nucl Med 1983;24:1108-1113.

53. Flint LM, Mays ET, Aaron WS. Selectivity in Management of Hepatic Trauma. Ann Surg 1977;185:613-618

54. Freeman LM, Mandell CH. Dynamic vascular scintigraphy of liver. Semin Nucl Med 1972;2:133-138.

55. Froelich JW, Simeone JF, McKusick KA, Winzelberg GG, Strauss HW. Radionuclide Imaging & US in Liver-Spleen Trauma: A prospective Comparison. Radiology 1982;145:457-461.

56. Gartman DM, Zeman RK, Cahow CE, Baker CC. Value of Hepatobiliary Scanning in Complex Liver Trauma. J Trauma 1985;25:887-891.

57. Geis WP, Schulz KA, Giacchino JL, Freeark RJ. The fate of unruptured intrahepatic haematoma's. Surgery 1981;90: 689-696.

58. Gelfand MJ. Scintigraphy in Upper Abdominal Trauma. Semin Roentgen 1984;19:296-307.

59. Gilday DL, Alderson PO. Scintigraphic evaluation of liver & spleen injury. Semin Nucl Med 1974;13:184-197.

60. Goldsmith SJ. Reticuloendothelial system localising agents.In: Rothfeld B, ed Nuclear Medicine: Hepatolienal. Philadelphia: Lippincott Co, 1980:12-23.

61. Gordon I. Effect of Nuclear Medicine on Paediatric Imaging. Br J Radiol 1993;66:971-985.

62. Grays' Anatomy. 34th ed. Davies DV, ed. London: Longmans Green & Co Ltd, 1969.

63. Grumbach K, Mechlin MB, Mintz MC. CT and US of the Traumatized & Acutely Ill Patient. Emerg Clin North Am 1985;3:607-624.

64. Hansen RM, Spiegelhoff DR. Marked Congenital Fissure Masquerading as Splenic Laceration.J Nucl Med 1981;22:151-152.

65. Hiatt JR, Harrier HD, Koenig BV, Ransom KJ. Nonoperative management of major blunt liver injury with haemoperitoneum. Arch Surg 1990;125:101-103.

66. Hollands MJ, Little JM. Role of hepatic resection in the management of blunt liver trauma.World J Surg 1990;14:478-482.

67. Howman-Giles R, Gilday DL, Venugopal S, Shandling B,Ash JM. Splenic Trauma-Non-operative Management & Long term follow up by Scintiscan. J Pediatr Surg 1978;13:121-126.

68. Jacobsson H, Larson SA, Ohlsen H. Specific considerations in interpretation of SPECT of liver. Eur J Nucl Med 1985;11:309-315.

69. Jalleh RP, Greco L, Habib NA. Liver Injury after trivial trauma. Hospital Update 1993;3:58-62.

70. Jaszczak RJ, Whitehead FR, Lim CB, Coleman RE. Lesion detection with SPECT compared with conventional imaging. J Nucl Med 1982;23:97-102.

71. Jeffrey RB. CT Diagnosis of Blunt Hepatic and Splenic Injuries. Radiology 1989;171:17-18.

72. Johnson RJ. Anatomy of the liver. In: Rothfeld B, ed. Nuclear Medicine:Hepatolienal. Philadelphia: Lippincott Co, 1980:1-11.

73. Jones TK, Walsh JW, Maull I. Diagnostic Imaging in Blunt Trauma of Abdomen. Surg Gynaecol Obstets 1983;157: 389-398.

74. Kaplan WD, Drum DE, Lokich JJ. The effect of cancer chemotherapeutic agents on the liver-spleen scan. J Nucl Med 1980;21:84-87.

75. Kaufman RA, Towbin R, Babcock DS, Gelfand MJ, Guice KS, Oldham KT, et al. Upper Abdominal Trauma in children: Imaging Evaluation. AJR 1984;142:449-460.

76. Kaufman R, Babcock DS. An Approach to Imaging the Upper Abdomen in Children. Semin Roenten 1984;19:308-320.

77. Keyes JW. Perspective on Tomography. J Nucl Med 1982;23:633-640.

78. Keyes JW, Singer D, Saterlee W, Kalff V, Harkness BA. Liver-Spleen studies with rotating gamma camera:II Utility of tomography. Radiology 1984;153:537-541.

79. Keyes JW. SPECT of the Liver. Semin Liver Dis 1989;9:77-85.

80. Khan O, Ell P J, Jarritt PH, Cullum ID, Williams ES. Comparison between emission and transmission computed tomography of the liver. Br Med J 1981;283:1212-1214.

81. Knopf DR, Torres WE, Fajman WJ, Sones PJ. Liver lesions: comparative Accuracy of Scintigraphy & CT. AJR 1982;138: 623-627.

82. Knudson MM, Lim RC, Oakes DD, Brooke Jeffrey R. Non-operative management of blunt liver injuries in adults:the need for continued surveillance. J Trauma 1990;30:1494-1500.

83. Krige JEJ, Terblanche J. Management of 34 Cases of Liver Injury. S Afr J Surg 1989:27:43.

84. Kuhn JP. Diagnostic Imaging for the Evaluation of Abdominal Trauma in Children. Pediatr Clin North Am 1985;32:1427-1447.

85. Lakhoo K, Bass DH, Cywes S. Blunt Splenic Trauma in Children. S Afr J Surg 1991;29:108-109.

86. Lin MS, Winchell HS. A "kit" method for the preparation of Tc-tin(II) colloid and a study of its properties. J Nucl Med 1972;13:58-65.

87. Little JM, McRae J, Smitananda MB, Morris JG. Radioisotope Scanning of Liver & Spleen in Upper Abdominal Trauma. Surg Gynaecol Obstet 1967;125:725-729.

88. Love,L. Radiology of Abdominal Trauma. JAMA 1975;231: 1377-80.

89. Luks FI, Lemire A, Oiumet A, St-Vil D, Di Lorenzo M, Filiatrault D. Blunt abdominal trauma in children:the practical value of US. J Trauma 1993;34:607-610.

90. Luna GK, Eddy AC, Copass M. Sensitivity of Vital Signs in Indentifying Major thoraco-abdominal Haemorrhage. Am J Surg 1989;157:512-515.

91. Lutzker LG, Chun KJ. Radionuclide imaging in non-surgical treatment of liver & spleen trauma. J Trauma 1981;21: 382-387.

92. Lutzker LG. Radionuclide Imaging of the Injured Spleen and Liver. Semin Nucl Med 1983;13:184-198.

93. Maas R, Alvarez J, Arriaga C. On a New Tracer for Liver Scanning. Intl J App Radiat & Isotopes 1967;18:653-654.

94. MacCarty RL, Wahner HW, Stephens DH, Sheedy PF, Hattery RR.Retrospective comparison of radionuclide scans and CT of the liver and pancreas. Am J Roentgen 1977;129:23-28.

95. Marx JA, Moore EE, Jorden RC, Eule J. Limitations of CT in the Evaluation of Acute Abdominal Trauma.J Trauma 1985;25:933-937.

96. Mc Afee JG, Ause RG, Wagner HN. Diagnostic Value of Scintillation Scanning of Liver. Arch Intl Med 1965;116: 95-110.

97. McAnena OJ, Moore EE, Marx JA. Initial Evaluation of the Patient with Blunt Abdominal Trauma. Surg Clin North Am 1990;70:495-515.

98. McClelland RR. Focal porta hepatis scan defects. What is their significance? J Nucl Med 1975;16:1007-1012.

99. McConnell B, McConnell R, Guiberteau MJ. Radionuclide Imaging in Blunt Trauma. Radiol Clin North Am 1981;19: 37-51.

100. Mc Connell DB, Trunkey DD. Non operative Management of Abdominal Trauma. Surg Clin North Am 1990;70:677-688.

101. McMullin M, Johnston G. Long term management of patients after splenectomy. BMJ (SA ed) 1994;2:248.

102. Mettler FA, Guiberteau MJ. Gastrointestinal Tract. In: Essentials of Nuclear Medicine Imaging. 3rd ed. Philadelphia: Saunders, 1991: 177-196.

103. Meyer AA, Crass RA, Lim RC, Brooke Jeffrey R, Federle MP, Trunkey DD. Selective non-operative management of blunt liver injury using CT. Arch Surg 1985;120:550-554.

104. Moar JJ. Autopsy Assessment of Liver Lacerations. S Afr Med J 1985;68:180-182.

105. Moon KL, Federle MP. CT in Hepatic Trauma. Am J Radiol 1983;141:309-314.

106. Moore E. Critical decisions in the management of hepatic trauma. Am J Surg 1984;148:712-16.

107. Moore FA, Moore EE, Seagraves A. Non-resectional management of major hepatic trauma. Am J Surg 1985; 150:725.

108. Mould RF. An Investigation of variations in normal liver shape. Br J Radiol 1972;45:586-590.

109. Nebesar RA, Rabinov KR, Potsaid MS. Radionuclide Imaging of Spleen in Suspected Splenic Injury. Radiology 1974;110:609-614.

110. Nelson J, Bresticker MA, Nahrwold DL. CT in the Initial Evaluation of Blunt Trauma. J Trauma 1992;33:722-727.

111. Ochsner MG, Jaffin JH, Golocovsky M, Jones RC. Major hepatic trauma. Surg Clin North Am 1993;73:337-352.

112. Olsen WR, Polley TZ. A Second Look At Delayed Splenic Rupture. Arch Surg 1977;112:422-425.

113. Olsen WR. Late complications of central liver injuries. Sugery 1982;92:733-740.

114. Oratz M, Rothschild MA, Schreiber SS. Hepatic Radionuclide Planar imaging. Semin Liver Dis 1989;9:7-15.

115. Oyamada H, Terui S, Makuuchi M, Yamazaki S, Hasegawa H, Okazaki N. Segmental Assessment on Ordinary Scintigrams & SPECT Images of Liver. Eur J Nucl Med 1984;9:161-167.

116. Peitzman AB, Makaroun MS, Slasky BS, Ritter P. A Prospective Study of CT in Initial Management of Blunt abdominal Trauma. J Trauma 1986;26:585-592.

117. Pettigrew RI, Witztum K, Perkins GC, Johnson ML, Burks RN, Verba JW. SPECT of the liver: Normal vascular intrahepatic structures. Radiology 1984;150:219-223.

118. Pettigrew R, Witztum K, Perkins GC, Halpern S, Verba J,et al. Vascular Intrahepatic Defects in SPECT of the Normal Liver as defined by ^{99m}Tc-RBC's & TSC. J Nucl Med 1983; 24:30.

119. Popovsky J,Wiener SN, Felder PA, Biramje A, Reydman M. Liver Trauma Conservative Management & Liver scan. Arch Surg 1974;108:184-186.

120. Pringle JH. Notes on the arrest of hepatic haemorrhage due to trauma. Ann Surg 1908;48:541-549.

121. Reid A, Dendy PP, Gemmel HG, Smith FW. Value of Tomo graphic Section Views in Identifying Liver Abnormalities by Scintigraphy.Acta Radiol Diag 1983;24:107-111.

122. Richards P, Tucker WD, Srivastava SC. ^{99m}Tc:An historical perspective. Intl J Appl Radiat Isot 1982;33:793-799.

123. Rosenthal L. Intravenous radionuclide angiography in diagnosis of trauma. Semin Nucl Med 1974;4:395-409.

124. Rosenthal SN. Are hepatic scans overused ? Am J Dig Dis 1976;21:659-663.

125. Rubin RA, Lichtenstein GR. Hepatic Scintigraphy in the Evaluation of Solitary Solid Liver Masses. J Nuc Med 1993;34:697-705.

126. Saha GB. Normal biodistribution of diagnostic radio-pharmaceuticals. In: Hladik, Saha & Study, ed. Essentials of Nuclear Medicine Science. Baltimore:Williams & Wilkins, 1987.

127. Sample WF, Gray RK, Poe ND, Graham LS, Bennett LR. Tomo graphic nuclear imaging and gray scale ultrasound in the evaluation of porta hepatis. Radiology 1977;122:773-779.

128. Sampson CB, ed. Textbook of Radiopharmacy: Theory & Practice (Vol 3). London: Gordon & Breach Science, 1990.

129. Sayers RD, Bewes PC, Porter KM. Emergency Laparotomy for Abdominal Trauma. Injury 1992;23:537-541.

130. Scalea T, Goldstein A, Phillips T, Sclafani SJA, Panetta T, McAuley J, et al. Analysis of 161 Falls from Height: The "Jumper Syndrome". J Trauma 1986;26:706-712.

131. Schweizer W, Huber A, Blumgart LH. Liver Injury. Surgery 1988;1:1471-1476.

132. Shackford SR, Molin M. Management of Splenic Injuries. Surg Clin North Am 1990;70:595-620.

133. Shah PA, Kulkarni SS, Joshi N, Lakshmy MV, Dewoolkar VV. Hepatic trauma: experience of 110 cases. Injury 1993;24: 303-305.

134. Sheldon GF, Rutledge R. Hepatic Trauma. Adv in Surg 1989;22:179-194.

135. Sherck JP, Mc Cort JJ, Oakes DD. CT in Thoraco-abdominal Trauma. J Trauma 1984;24:1015-1021.

136. Sherck J, Oakes D. Intestinal injuries missed by CT. J Trauma 1990;30:1-7.

137. Sherlock DJ, Bismuth H. Secondary surgery for liver trauma. Br J Surg 1991;78:1313-1317.

138. Siegel JH, Mason-Gonzalea S, Dischinger P, Cushing B, Read K, Robinson R. Safety-belt restraints & compartment intrusions in frontal & lateral motor vehicle crashes. J Trauma 1993;5:736-758.

139. Sodee DB, Ballistrea M. Diagnostic Accuracy of Nuclear Medicine SPECT Imaging. Nuc Med Biol 1987;14:191-204.

140. Soderstrom CA, Du Priest RW, Cowley RA. Pitfalls of Perintoneal Lavage in Blunt Abdominal Trauma. Surg Gynaecol Obstet 1980;151:513-518.

141. Sorenson JA, Phelps ME. Physics in Nuclear Medicine. 2nd ed. Philadelphia: Saunders, 1987.

142. Subramanian G, McAfee J. Stannous oxide colloid labelledwith ^{99m}Tc or ^{113m}In for Bone Marrow Imaging. J Nucl Med 1970;11:365 (abstr).

143. Starinsky R,Melzer M,Pajewski M. Blunt Abdominal Trauma with Unrecognized Urinary Tract Injury.Isr J Med Sci 1984;20:401-4.

144. Strauss L, Bostel F, Clorius JH, Raptou E, Wellman H, Georgi P. SPECT for Assessment of Hepatic Lesions. J Nucl Med 1982;23:1059-1065.

145. Sty JR, Miller JH, Starshak RJ. Paediatric Nuclear Medicine. Baum S, ed. Conneticut: Appleton-Century Crofts,1983.

146. Theron EJ. Management of Blunt Abdominal Injuries. Trauma-J Accident & Emerg Med 1990;7:76-83.

147. Trollope Ml, Stalnaker Rl, Frey CF, McElhaney JH. Mechanism of Injury in Blunt Abdominal Trauma. J Trauma 1973;13:962-970.

148. Trunkey DD, Shires GT, McClelland R. Management of Liver Trauma in 811 Consecutive Patients. Ann Surg 1974;179: 722-728.

149. Tryfonas G, Georgiou G, Lagazalis G, Gavopoulos S, Grigoriadis G. Current management of liver and splenic blunt trauma in children. Paed Surg Intl 1990;5:437-442.

150. Uthoff LB, Wyffels PL, Adams CS, Zwicky GF, Berg BC. A prospective study comparing Nuclear Scintigraphy & CT in Initial evaluation of Trauma Patient. Ann Surg 1983;198: 611-616.

151. Van Der Spuy J. Violence in Perspective. Trauma Review 1993;1:1-6.

152. Van Heertum RL, Brunetti JC, Yudd AP. Abdominal SPECT Imaging. Semin Nucl Med 1987;17:230-246.

153. Van Heertum RL, Yudd AP, Brunetti JC, Pennington MR, Gualtieri NM. Hepatic SPECT Imaging in the detection & Clinical Assessment of Hepatocellular Disease. Clin Nuc Med 1992;17:948-953.

154. Walt, AJ. Mythology of Hepatic Trauma or Babel Revisited. Am J Surg 1978;135:12-18.

155. Watson CJ, Calne RY, Padhani AR, Dixon AK. Surgical restraint in the management of liver trauma. Br J Surg 1991;78:1071-1075.

156. Watson DI, Williams AR. Management of the traumatized liver:an appraisal of 63 cases. Austr N Z J Surg 1989;59:137-142.

157. Waxman AD, Apau R, Siemsen JK. Rapid sequential liver imaging. J Nucl Med 1972;13:522-524.

158. Weissmann HS, Byun KJC, Freeman LM. Role of ^{99m}Tc IDA Scintigraphy in the Evaluation of Hepatobiliary trauma. Semin Nucl Med 1983;13:199-222.

159. Wilkinson E. Review of diagnostic methods in abdominal trauma. S Afr J Surg 1989;27:49-56.

160. Wilson RH, Moorehead RJ. Management of splenic trauma. Injury 1992;23:5-9.

161. Wolfman NT, Bechtold RE, Scharling ES, Meredith JW. Blunt Upper Abdominal Trauma:Evaluation by CT. AJR 1992;158: 493-501.

162. Yamamoto F, Pu Y, Igimi H, Kojima T, Witt JL, Yamamoto S. MRI of traumatic hepatic laceration:evaluation of healing after surgery. Abdom Imaging 1993;18:253-257.

163. Yudd AP, Van Heertum RL, Brunetti JC. Evaluation of liver Disease SPECT versus CT. J Nucl Med 1986;27:924.

164. Yudd AP, Van Heertum RL, Brunetti JC. SPECT and Transmission Computed Tomography in the Evaluation of Liver Disease. Clin Nuc Med 1988;13:397-401.

APPENDIX A

PATIENT DATA SHEET

LIVER-SPLEEN SCINTIGRAPHY IN BLUNT ABDOMINAL TRAUMA

Patient sticker :

PERSONAL DATA

Sex : male female

Age :

HISTORY

Injury	date:	time:
Admission	date:	time:
Scan	date:	time:

MECHANISM OF INJURY

MVA pedestrian	fall from height
MVA passenger	blunt assault
MVA cyclist	sharp assault - instrument
MVA driver	other

SYPTOMS

abdominal pain
chest pain
chest pain on coughing only
other

PAST HISTORY

Medical (list)
Surgical (list)
Past abdominal trauma
Past abdominal surgery

EXAMINATION

GENERAL:

pulse
blood pressure SHOCK
respiratory rate
pallor

CHEST:

tachyopnoea
lower chest tenderness
bruising chest wall
abrasions chest wall
other

ABDOMEN:

bowel sounds absent
bruising abd wall
abrasions
tender
guarding
rebound tenderness
abdominal distension
other

DOES THE ABDOMINAL EXAMINATION MAKE ONE SUSPICIOUS ?
YES NO OTHER

ORTHOPAEDIC injuries:

list

CNS:

evidence of head injury
GCS: E M V =
intoxicated
neurological deficits

CARDIAC:

OTHER:

PERITONEAL LAVAGE:

not done negative
positive (describe degree)

INVESTIGATIONS

FBC:

HB	NORMAL
Platelets	
falling HB	

SMAC:

urea	NORMAL
Na+	
K+	

CXR:

rib #: left	NORMAL
right	
lung contusions	
haemothorax	
pneumothorax	
widened mediastinum	
other	

AXR:

ileus	NORMAL
fluid	
air under diaphragm	
other	

ULTRASOUND:

not done	NORMAL
FINDINGS:	

IVP:

not done	NORMAL
FINDINGS:	

CT SCAN:

not done	NORMAL
FINDINGS:	

LIVER-SPLEEN SCAN RESULT:

time post-injury (not post-admission): ______hours

FINDINGS: NORMAL

MANAGEMENT:

Conservative

Surgery:
laparotomy
FINDINGS: NO LIVER/SPLEEN TRAUMA

Other Surgery: (eg. orthopaedic)
FINDINGS:

FINAL DIAGNOSIS:

APPENDIX B

RESULT SHEET USED BY INDEPENDENT REVIEWER

PATIENT STICKER :
RESULTS

DYNAMIC STUDY FINDINGS	
FINDINGS - LIVER : **- SPLEEN:**	
SPECT STUDY FINDINGS	
LIVER	
- HAEMATOMA **POSITION** **SIZE** **(SMALL, MOD, LARGE)** **- CONTUSION** **POSITION** **SIZE** **- LACERATION** **POSITION** **SIZE**	
SPLEEN	
- HAEMATOMA **- CONTUSION** **- LACERATION**	

FINAL OUTCOME

DETECTION OF TRAUMATIC LESION : YES NO

IN LIVER :

IN SPLEEN :

APPENDIX C

LIVER INJURIES ONLY

Pt. no.	Initial result	Reviewers result	Final Result
1	N	N	N
2	N	N	N
3	N	N	N
4	N	N	N
5	N	N	N
6	N	N	N
7	*L & C*	*L & C*	*L & C*
8	N	N	N
9	*H*	N	*H*
10	N	N	N
11	N	N	N
12	*C*	*C*	*C*
13	*L*	N	*L*
14	*L*	*L*	*L*
15	N	N	N
16	N	N	N
17	N	N	N
18	N	N	N
19	*C*	*C*	*C*
20	N	N	N
21	*C X 2*	N	*C X 1*
22	N	N	N
23	N	N	N
24	N	*C*	*C*
25	N	N	N
26	N	N	N
27	N	N	N
28	N	N	N
29	N	N	N
30	N	N	N
31	N	N	N
32	*L & C*	N	*L & C*
33	N	N	N
34	N	N	N
35	N	N	N
36	N	N	N
37	N	N	N
38	*C*	*C*	*C*
39	N	N	N
40	*L & H*	N	*L & H*
41	N	N	N
42	N	N	N
43	N	N	N
44	*L & H*	*L & H*	*L & H*
45	N	N	N
46	N	N	N
47	N	N	N
48	N	N	N
49	N	*C*	*C*
50	N	N	N

51	N	N	N
52	*H*	*H*	*H*
53	N	N	N
54	N	N	N
55	N	N	N
56	N	N	N
57	*L*	N	N
58	*L & H*	*L & H*	*L & H*
59	N	N	N
60	N	N	N
61	*L*	N	*L*
62	*L*	N	*L*
63	N	N	N
64	N	N	N
65	N	N	N
66	*H*	*L*	*L*
67	*L*	*L & H*	*L & H*
68	N	N	N
69	*L*	N	N
70	N	N	N
71	N	N	N
72	N	N	N
73	*C*	N	N
74	*C*	N	*C*
75	N	N	N
76	N	N	N
77	*C*	N	N
78	N	N	N
79	*L*	N	+/-
80	N	N	N
81	*L*	*L*	*L*
82	N	N	N
83	*C X 2*	N	*C X 1*
84	N	*L*	N
85	N	N	N
86	*L & H*	*L & H*	*L & H*
87	*L*	+/-	+/-
88	N	N	N
89	N	*C*	*C*
90	*L*	N	+/-
91	*L*	+/-	*L*
92	*C*	N	*C*
93	*L*	*L*	*L*
94	*L & H*	*L & H*	*L & H*
95	N	N	N
96	N	N	N
97	N	N	N
98	N	N	N
99	N	N	N
100	N	N	N

N = NORMAL
L = LACERATION
H = HAEMATOMA
C = CONTUSION

L & H = LACERATION & HAEMATOMA
L & C = LACERATION & CONTUSION
X 2 = TWO LESIONS
X 1 = ONE LESION

SPLEEN INJURIES ONLY

Pt. no.	Initial result	Reviewers result	Final Result
1	N	N	N
2	N	N	N
3	*H*	*H*	*H*
4	N	N	N
5	N	N	N
6	N	N	N
7	N	N	N
8	N	N	N
9	N	N	N
10	N	N	N
11	N	N	N
12	N	N	N
13	N	N	N
14	N	N	N
15	N	N	N
16	N	N	N
17	N	N	N
18	N	N	N
19	N	N	N
20	N	N	N
21	N	N	N
22	N	N	N
23	N	N	N
24	N	N	N
25	N	N	N
26	*L*	*L*	*L*
27	N	N	N
28	*L & H*	*L & H*	*L & H*
29	N	N	N
30	N	N	N
31	N	N	N
32	N	N	N
33	N	N	N
34	N	N	N
35	*H*	N	N
36	N	N	N
37	*M*	*M*	*M*
38	*L*	*L*	*L*
39	N	N	N
40	N	N	N
41	N	N	N
42	N	*L*	*L*
43	*H*	N	N
44	N	N	N
45	N	N	N
46	N	N	N
47	*L*	N	*L*
48	*L & H*	*L & H*	*L & H*
49	N	N	N
50	N	N	N
51	N	N	N

52	N	N	N
53	N	N	N
54	*L*	*L*	*L*
55	N	N	N
56	N	N	N
57	N	N	N
58	N	N	N
59	N	N	N
60	N	N	N
61	N	N	N
62	N	N	N
63	N	N	N
64	*L*	*L*	*L*
65	N	N	N
66	N	N	N
67	N	N	N
68	N	N	N
69	*H*	*L*	*L*
70	N	N	N
71	N	N	N
72	N	N	N
73	N	N	N
74	N	N	N
75	N	N	N
76	N	N	N
77	N	N	N
78	N	N	N
79	N	N	N
80	N	N	N
81	N	N	N
82	N	N	N
83	N	N	N
84	N	N	N
85	N	N	N
86	N	N	N
87	*A*	N	*C*
88	N	N	N
89	N	N	N
90	N	N	N
91	N	N	N
92	N	N	N
93	*H*	*H*	*H*
94	N	N	N
95	N	N	N
96	N	N	N
97	N	N	N
98	N	N	N
99	N	N	N
100	N	N	N

N = NORMAL
C = CONTUSION
M = MINIMAL ACTIVITY
A = ABSENT ACTIVITY
L = LACERATION
L&H= LACERATION & HAEMATOMA