

58880 030

LUMEDW - MEXL --

1016 - 01 - 112 (1986).

**RADIOLOGICAL PROCEDURES  
OF THE BILIARY TRACT  
AND THEIR COMPLICATIONS**

**Ulf Nilsson**



**Lund 1986**

DOKUMENTDATABLAD  
ent SIS 61 41 21

<b>Organization</b> <b>LUND UNIVERSITY</b> Department of Diagnostic Radiology University Hospital, S-221 85 Lund Sweden		<b>Document name</b> <b>DOCTORAL DISSERTATION</b>	
		<b>Date of issue</b> September 5, 1986	
		<b>CODEN:</b> LUMEDW/(MEXL-1016)/01- 112 (1986)	
<b>Author(s)</b> Ulf Nilsson		<b>Sponsoring organization</b>	
<b>Title and subtitle</b> Radiological procedures of the biliary tract and their complications			
<b>Abstract</b> In order to assess the incidence and type of complications at PTC and transhepatic bile duct intubation three different patient populations were investigated retrospectively. Information from angiography (n = 83), CT (n = 23), PTC examinations (n = 237) and medical records were analysed in order to detect complications caused by the transhepatic procedures. Complications were observed in 17 - 33 %, treatment was required in 4 - 6 % and procedure related mortality was 1 - 2 % in the different materials. A randomised prospective clinical investigation in 200 consecutive patients was performed to evaluate the diagnostic efficacy of preoperative intravenous infusion cholangiography (PIC) with iotroxate as compared to that of operative cholangiography (OC) and to assess the incidence of complications. Bile duct calculus was underdiagnosed with PIC in 1/124 patients and overdiagnosed with OC in 3/124 patients examined with both methods. PIC was found to reduce operating time significantly. Only two minor (1 %) and no severe or fatal reactions to iotroxate were noted. An experimental model was set up to study the morphology of surgically created stenotic bile duct anastomoses in 13 pigs before and after transhepatic balloon catheter dilatation. In pigs not dilated by balloon catheter a fibrotic stenosis persisted during a follow-up period of 25 weeks. Transhepatic balloon catheter dilatation of the stenotic area caused a bile duct wall lesion which resulted in a fibrous healing that was almost complete after four weeks. An initial increase of the stricture diameter was followed by partial restenosis in the short-term follow-up.			
<b>Key words</b> Percutaneous transhepatic cholangiography, Bile duct drainage, Angiography, Computed tomography, Intravenous cholangiography, Contrast media, Balloon dilatation, Experimental, Complications			
<b>Classification system and/or index terms (if any)</b>			
<b>Supplementary bibliographical information</b>		<b>Language</b> English	
<b>ISSN and key title</b>		<b>ISBN</b>	
<b>Recipient's notes</b>		<b>Number of pages</b> 112	<b>Price</b>
		<b>Security classification</b>	

**Distribution by (name and address)** Dr Ulf Nilsson

Dept of Diagn Radiology, Helsingborg Hospital, S-251 87 Helsingborg Sweden

I, the undersigned, being the copyright owner of the abstract of the above-mentioned dissertation, hereby grant to all reference sources permission to publish and disseminate the abstract of the above-mentioned dissertation.

Signature \_\_\_\_\_

Ulf Nilsson

Date Lund July 15th, 1986

R A D I O L O G I C A L   P R O C E D U R E S  
O F   T H E   B I L I A R Y   T R A C T  
A N D   T H E I R   C O M P L I C A T I O N S

ULF NILSSON

Leg. läk., Halland

Akademisk avhandling som med vederbörligt tillstånd av  
Medicinska Fakulteten vid Universitet i Lund  
för avläggande av medicine doktorsexamen  
kommer att offentligen försvaras i Föreläsningssal 3,  
Centralblocket, Lasarettet i Lund, fredagen den 5 september  
1986, kl 09 00



E R R A T A

Page 13 line 4... should read:

2.3 MATERIAL AND METHODS FOR EVALUATING THE DIAGNOSTIC EFFICACY OF PREOPERATIVE INTRAVENOUS INFUSION CHOLANGIOGRAPHY AND OPERATIVE CHOLANGIOGRAPHY

page 33 line 14... should read:

The complication rate of transhepatic or endoscopic biliary drainage should be compared to a reported operative mortality of 16 to 40 percent /55,161,49/.

In the references, please correct as follows:

1. ALLEN M., BORODY T., BUGLIOSI T., MAY G., LaRUSSO N. and THISTLE J.: Cholelitholysis using methyl tertiary butyl ether. Gastroenterology 88 (1985), 122
25. CLEVELAND R., JACKSON M., NEWMAN P. and NELSON R.: Traumatic intrahepatic hepatic artery-portal vein fistula with associated hemobilia. Ann Surg 171 (1970), 451
32. CRANLEY B. and LOGAN H.: Exploration of the common bile duct - the relevance of the clinical picture and the importance of peroperative cholangiography. Brit J Surg 67 (1980), 869
43. DOYLE P.J., WARD-McQUAID J.N. and McEWEN SMITH A.: The value of routine peroperative cholangiography - a report of 4000 cholecystectomies. Brit J Surg 69 (1982), 617
53. FLETCHER M., BRINKLEY D., DAWSON J., NUNNERLEY J., WHEELER P. and WILLIAMS R.: Treatment of high bileduct carcinoma by internal radiotherapy with Iridium-192 wire. Lancet 2 (1981), 172
54. FORK F-T., NYLANDER G. and OLIN T.: Bilateral videosi-g-nalkommunikation mellan kir.op. och röntgenavd. med digital röntgenbildbehandling i samband med peroperativa röntgenundersökningar, MAS., Malmö. Scand Radiol Soc (Proc 41st Congr) (1983) (In Swedish)
84. KEIGHLEY M.: Micro-organisms in the bile: A preventable cause of sepsis after biliary surgery. Ann Roy Coll Surg Engl 59 (1977), 328
96. MACK E., CRUMMY A. and BABAYAN V.: Percutaneous trans-hepatic dissolution of common bile duct stones. Surgery 90 (1981), 584
108. MIRRIZZI P.L.: Operative cholangiography. Surg Gynecol Obstet 65 (1937), 702

128. PEREZ M., OLEAGA J., FREIMAN D., McLEAN G. and RING E.: Removal of a distal common bile duct stone through percutaneous transhepatic catheterization. Arch Surg 104 (1979), 107
153. THOMPSON W.M., BURBANK F.H., FREIMARCK R.D., HALL A. and HEDLUND L.W.: Digital radiographic evaluation of the bile ducts. Invest Radiol 20 (1985), 956
170. WOLOCHOW H., HILDEBRAND G.J. and IAMANA C.: Translocation of microorganisms across the intestinal wall of the rat: Effect of microbial size and concentration. J Infect Dis 116 (1966), 523

Minor typing errors are not included in this errata list.

From the Department of Diagnostic Radiology (Head: Professor  
Erik Boijesen), University Hospital, S-221 85 Lund, Sweden

R A D I O L O G I C A L   P R O C E D U R E S  
O F   T H E   B I L I A R Y   T R A C T  
A N D   T H E I R   C O M P L I C A T I O N S

ULF NILSSON

Leg. läk., Halland

Lund 1986

The English language was revised by Dr Stephen Frost

To my precious companions

NETTA, HANNA and OLA

*Tryck: Litos Reprotryck i Malmö AB, 1986*

This thesis is based on the following papers which will be referred to in the text by their Roman numerals:

- I. Jürgen Hoevels and Ulf Nilsson: Intrahepatic vascular lesions following nonsurgical percutaneous transhepatic bile duct intubation. *Gastrointest Radiol* 5 (1980), 127-135
- II. Ulf Tylen, Jürgen Hoevels and Ulf Nilsson: Computed tomography of iatrogenic hepatic lesions following percutaneous transhepatic cholangiography and portography. *J Comput Assist Tomogr* 5 (1981), 15-18
- III. Ulf Nilsson, Anders Evander, Ingemar Ihse, Anders Lunderquist and Alida Mocibob: Percutaneous transhepatic cholangiography and drainage. Risks and complications. *Acta Radiol Diagnosis* 24 (1983), 433-439
- IV. Gunnar Alinder, Ulf Nilsson, Anders Lunderquist, Per Herlin and Torsten Holmin: Pre-operative infusion cholangiography compared to routine operative cholangiography at elective cholecystectomy. *Br J Surg* 73 (1986), 383-387
- V. Ulf Nilsson: Adverse reactions to iotroxate at intravenous cholangiography. A prospective clinical investigation and review of the literature. Accepted for publication in *Acta Radiol Diagnosis* (1986)
- VI. Ulf Nilsson, Leif Ekelund, Lars Erik Hammarström, Torsten Holmin and Nils Jonsson: Balloon catheter dilatation of stenotic common bile duct anastomosis in the pig. A pilot study. Accepted for publication in *Acta Radiol Diagnosis* (1986)



C O N T E N T S		Page
1.	I N T R O D U C T I O N	7
2.	C L I N I C A L   M A T E R I A L S   A N D M E T H O D S	8
2.1.	<u>Radiological procedures</u>	8
2.1.1.	Percutaneous transhepatic fine needle cholangiography (I, II, III, VI)	8
2.1.2.	Percutaneous transhepatic biliary drainage (I, II, III, VI)	9
2.1.3.	Percutaneous transhepatic portography (II, III)	9
2.1.4.	Preoperative intravenous infusion chol- angiography (IV, V)	10
2.1.5.	Operative cholangiography (IV)	10
2.2.	<u>Materials and methods used in evaluating complications of radiological procedures</u>	10
2.2.1	Angiography (I)	10
2.2.2.	Computed tomography (II)	11
2.2.3.	Cholangiography and clinical findings	11
2.2.3.1.	Percutaneous transhepatic cholangiography (III)	11
2.2.3.2.	Preoperative intravenous infusion chol- angiography (IV, V)	12
2.2.3.3.	Operative cholangiography (IV)	13
2.3.	<u>Material and methods for evaluating the diagnostic efficacy of preoperative in- travenous infusion cholangiography and operative cholangiography</u>	13
3.	R E S U L T S   O F   C L I N I C A L I N V E S T I G A T I O N S	14
3.1.	<u>Complications of radiological procedures observed using</u>	15
3.1.1.	Angiography (I)	15
3.1.2.	Computed tomography (II)	16
3.1.3.	Cholangiography and clinical findings	16

3.1.3.1.	Percutaneous transhepatic cholangiography and drainage (III)	16
3.1.3.2.	Preoperative intravenous infusion cholangiography (V)	19
3.1.3.3.	Operative cholangiography (IV)	19
3.2.	<u>Diagnostic results of cholangiography (IV)</u>	19
3.2.1.	Preoperative intravenous infusion cholangiography	19
3.2.2.	Operative cholangiography	20
4.	E X P E R I M E N T A L I N V E S T I G A T I O N	21
4.1.	<u>Material and methods (VI)</u>	21
4.1.1.	Creation of bile duct strictures	21
4.1.2.	Transhepatic cholangiography	22
4.1.3.	Balloon catheter dilatation	22
4.1.4.	Histology	22
4.2.	<u>Results (VI)</u>	23
4.2.1.	Strictures not dilated by balloon catheters	23
4.2.2.	Strictures dilated by balloon catheters	23
5.	D I S C U S S I O N	24
5.1.	<u>Complications of percutaneous transhepatic procedures</u>	24
5.1.1.	Vascular lesions	24
5.1.2.	Parenchymatous lesions	27
5.1.3.	Clinical complications	28
5.2.	<u>Preoperative intravenous infusion cholangiography and operative cholangiography</u>	33
5.2.1.	Diagnostic efficacy	33
5.2.2.	Complications	35
5.3.	<u>Experimental bile duct strictures</u>	36

		Page
6.	C O N C L U S I O N S	37
7.	R E F E R E N C E S	39
I.	Intrahepatic vascular lesions following nonsurgical percutaneous transhepatic bile duct intubation	(127)
II.	Computed tomography of iatrogenic hepatic lesions following percutaneous transhepatic cholangiography and portography	(15)
III.	Percutaneous transhepatic cholangiography and drainage. Risks and complications	(433)
IV.	Pre-operative infusion cholangiography compared to routine operative cholangiography at elective cholecystectomy	(383)
V.	Adverse reactions to iotroxate at intravenous cholangiography. A prospective clinical investigation and review of the literature	V:1
VI.	Balloon catheter dilatation of stenotic common bile duct anastomoses in the pig. A pilot study	VI:1

## 1. INTRODUCTION

Percutaneous transhepatic cholangiography (PTC) and intravenous infusion cholangiography are well established as methods for evaluating bile duct morphology. Both methods have been refined during the last two decades. The fine needle technique, developed at Chiba University in Japan /123,124/, has reduced complications at diagnostic PTC /8, 113,124/. Application of the Seldinger technique at PTC, allowing as it does the insertion of a catheter into the bile ducts, has opened up therapeutic possibilities for this method in patients with obstructive jaundice. Thus PTC is now widely used in a number of biliary tract procedures including drainage as a preoperative /37,62,68,72,104,117,120, 150,165/ or palliative step /8,50,77,127/ and therapy in infectious cholangitis /50,66,82,122,150/.

The technique also allows collection of brush and forceps biopsies /33,47,71,90,97,106,116/, insertion of endoprostheses /20,28,39,78,92,115,166/ and of radiation sources in intracavitary radiotherapy /27,53,76,111,132/.

Other transcatheter applications are extraction /26,42,128, 167/, crushing /93/ and dissolution of bile duct calculi /1, 79, 96,147/ as well as dilatation of biliary strictures /21, 58,100,110,140,152,158/.

Infusion cholangiography has also been improved by the advent of better contrast media. Because of the necessity of inserting needles, catheters and contrast media into the human body, both methods carry a risk of complications which must be taken into account when deciding the optimum diagnostic and therapeutic modality for the patient with a biliary disorder.

The aims of the present investigations (I-VI) were:

- To assess the incidence and type of complications at PTC and transhepatic catheter insertion into the bile ducts (I-III).

- To evaluate the complications and diagnostic efficacy of preoperative infusion cholangiography using iotroxate (IV-V)
- To study biliary strictures prior to and after percutaneous transhepatic balloon catheter dilatation in an experimental model in the pig (VI).

## 2. CLINICAL MATERIALS AND METHODS

Three different patient populations subjected to PTC and transhepatic bile duct intubation were investigated retrospectively. Information from radiological examinations including angiography (I), computed tomography (II) and data collected from the PTC examinations and medical records (III) were analysed to assess the incidence and type of vascular, parenchymatous and clinically detectable complications caused by the transhepatic procedures.

A randomised prospective clinical investigation (IV) was performed to evaluate the diagnostic efficacy of preoperative intravenous infusion cholangiography (PIC) with iotroxate as compared to that of operative cholangiography (OC) and to assess the incidence of complications (V).

### 2.1. RADIOLOGICAL PROCEDURES

#### 2.1.1. Percutaneous transhepatic fine needle cholangiography (I, II, III, VI)

Under fluoroscopic control, with the patient supine, a 15 cm fine needle (OD 0.9 mm) was inserted intercostally, in the mid-axillary line, parallel to the table top, towards the hilum of the liver. The needle was slowly withdrawn while contrast medium was being injected. If necessary, up to 10

punctures were performed until contrast medium was seen in the biliary tree. The biliary system was then filled with contrast medium.

#### 2.1.2. Percutaneous transhepatic biliary drainage (I, II, III, VI)

If biliary duct obstruction was diagnosed at fine needle PTC, percutaneous transhepatic drainage (PTD) was achieved by performing a new puncture from the same external location with a 20-25 cm radiopaque polyethylene sheathed stylet (OD/ID 1.6/1.0 mm, Surgimed, Denmark). A peripheral bile duct of the right liver lobe was then entered under bi-plane fluoroscopic control. A guide-wire was introduced and a catheter advanced towards the obstruction. Attempts were made to pass the occlusion. The puncture catheter was then exchanged, over a Lunderquist guide-wire, for a drainage catheter with multiple side holes. These were positioned both above and below the obstruction which allowed internal and external drainage, assuming that the occlusion had been passed. When separate drainage of the left liver lobe was required, an anterior approach was employed. Survey radiography of the liver was then performed daily for one week, any dislodgement of the drainage catheter thereby being revealed.

#### 2.1.3. Percutaneous transhepatic portography (II, III)

Percutaneous transhepatic catheterisation of the portal vein (PTP) was achieved using an approach and technique similar to that used to perform PTD and as described by HOEVELS et coll /77/. PTP was carried out to determine whether or not a tumour was resectable, to confirm or deny the existence of portal hypertension, or to enable portal venous sampling. When a radiopaque polyethylene catheter (OD/ID 1.6/1.0 mm) had been successfully introduced into a portal branch, catheterisation of the portal vein and its tributaries was achieved using variously shaped guide-wires.

#### 2.1.4. Preoperative intravenous infusion cholangiography (IV, V)

The patients were subjected to routine bowel cleansing. They also were prescribed a fluid intake in excess of 3 litres during the 24 hours prior to examination. Radiographs were taken after intravenous infusion of 100 ml (50 mg I/ml) meglumine iotroxate (Biliscopin, Schering, Berlin) over a period of 30 minutes. The patients were examined in the right posterior oblique position (approximately 20 degrees) and compression was applied over the abdomen. Great care was exercised when centering and collimating. Linear tomograms were then taken (Philips' Danatom, 22 degree angle) at 0.5 cm intervals.

#### 2.1.5. Operative cholangiography (IV)

Prior to removal of the gallbladder two anterior-posterior radiographs were taken after injection of 2 and 4 ml of the contrast medium through a thin plastic catheter inserted into the cystic duct. One right posterior oblique and one left posterior oblique radiograph were taken after injection of an additional 6 and 8 ml of the contrast medium. The exposures were made, after careful centering and collimation over the biliary tree, at 80-90 kV, using a stationary grid. Intraoperative choledochoscopy was performed in 17 out of 21 patients, subjected to choledocholithotomy or choledochotomy.

### 2.2. MATERIALS AND METHODS USED IN EVALUATING COMPLICATIONS OF RADIOLOGICAL PROCEDURES

#### 2.2.1. Angiography (I)

Hepatic angiography was performed after PTD in 83 patients, aged 33 to 88 years (mean 64). All of the patients had jaundice due to extrahepatic cholestasis. Vitamin K<sub>1</sub> was admin-

istered. The platelet count and activated partial thromboplastin time (APTT) were noted. Seventy-nine of the patients had a malignant tumour, 3 had extrahepatic gallstones and the remaining one had pancreatitis. Angiography was performed to assess tumour resectability in most patients. The diagnoses were verified by percutaneous fine needle aspiration biopsy and cytology, by operation or by post-mortem examination. PTC and insertion of a drainage catheter had been carried out one to 70 days (mean 13 days) prior to angiography. Coeliac angiography was performed in 31 patients and simultaneous coeliac and superior mesenteric angiography in the remaining 52. In addition, the hepatic artery was examined selectively in 35 patients.

#### 2.2.2. Computed tomography (II)

CT (Philips' Tomoscan 300) of the liver, slice thickness 12 mm at 18 mm intervals, was performed in 22 jaundiced patients aged 40 to 85 years after PTD (23 examinations) and in 10 patients aged 33 to 69 years after PTP. The examinations were done following an intravenous bolus injection of contrast medium (100 ml Isopaque Cerebral: 280 mg I/ml) in all but 2 cases. Two patients were examined both before and after injection of contrast medium. CT examinations were performed within 10 days of the transhepatic procedure in 27 cases and from 11 to 45 days after the procedure in 6 cases. The attenuation values of the lesions were determined and compared with those of the surrounding liver parenchyma and the aorta.

#### 2.2.3. Cholangiography and clinical findings

##### 2.2.3.1. Percutaneous transhepatic cholangiography (III)

Cholangiograms and protocols from a total of 237 PTC and PTD procedures performed on 182 jaundiced patients (98 women and 84 men; aged 22 to 95 years) were reviewed together with the patients' clinical files. Diagnoses were confirmed by means



of cytology, histology or operation in 162 out of 182 patients (89 %). Malignancy was found in 119 out of 182 patients (65 %).

Examinations were performed once in 140, twice in 32, thrice in 7 and four times in 3 patients. On 184 occasions a PTD was established with the tip of the drainage catheter above the obstruction in 81, below the obstruction but in the bile duct in 15 and out in the duodenum in 86. The right and left ducts were drained separately in 2 patients.

The transhepatic procedure was followed by fine needle (OD 0.9 mm) aspiration biopsy of an obstructing lesion in 73 patients and PTP (OD 1.6 mm) in 13 patients.

#### 2.2.3.2. Preoperative intravenous infusion cholangiography (IV, V)

The occurrence of the following complications was noted in a protocol: rash, nausea, vomiting, dizziness, shortness of breath, pain at the infusion site, anaphylactic shock and other reactions. The systolic blood pressure immediately before and after infusion of contrast medium was also noted. In addition, therapeutic measures necessitated by adverse reactions were recorded.

In the study of adverse reactions to iotroxate (V) only those 4 patients on whom infusion cholangiography was performed on an emergency basis, without previous bowel and fluid preparation, were excluded.

All clinical reports found in the literature on the toxicity of iotroxate were reviewed. When other contrast media were used for comparison, the complications observed were also included in the review.

#### 2.2.3.3. Operative cholangiography (IV)

Any complications deemed to be due to OC were noted in the patient's clinical records and in the radiologist's report.

#### 2.3. MATERIAL AND METHODS FOR EVALUATING THE DIAGNOSTIC EFFICACY OR PREOPERATIVE INTRAVENOUS INFUSION CHOLANGIOGRAPHY AND OPERATIVE CHOLANGIOGRAPHY

Two hundred consecutive patients admitted for elective cholecystectomy were examined with intravenous infusion cholangiography (PIC) on the day before scheduled operation. Informed consent was obtained from the patients and the study was approved by the Hospital Ethics Committee. After PIC the patients were randomised to form one of two groups. Thirteen of the 200 randomised patients were excluded from the study because of postponed operation in 7, explorative laparotomy in 2 and emergency examination in 4 patients. Ninety-six of the remaining patients had been randomised to group 1 and 91 to group 2. In group 1, the cholangiograms were filed and the findings not reported to the operating surgeon. All group 1 patients were subjected to operative cholangiography (OC) which provided the diagnostic basis for the surgical procedure in this group. All radiological examinations were classified as normal, pathological or inconclusive. The PIC's were later viewed independently by two senior radiologists and the findings compared with the findings at OC. PIC was regarded as pathological or inconclusive unless classified as normal by both radiologists.

In group 2, the PIC's were interpreted by two or more senior radiologists and demonstrated preoperatively to the operating surgeon. If PIC was normal, OC was not performed; otherwise OC was carried out prior to removal of the gallbladder. A hepatic duct or common bile duct exceeding 10 mm diameter, as measured on the film, was regarded as pathological. In

both PIC and OC, the magnification was approximately 25 per cent.

T-tube cholangiography was performed during the first post-operative week in 20 out of 21 patients subjected to exploration of the common bile duct. All patients were offered follow-up, including clinical examination and chemical laboratory investigations, 1, 3, 12 and 60 months postoperatively.

Statistical differences were determined using Student's t-test.

### 3. RESULTS OF CLINICAL INVESTIGATIONS

A summary of complications at PTD (I, II, III) is presented in Table 1.

TABLE 1. Summary of complications at PTD procedures observed using three different radiological methods

	Angio- graphy (I) %	C T (II) %	P T C (III) %
	n = 83	n = 23	n = 237 <sup>x</sup>
Incidence of complications	33	17	21
Complications requiring treatment	6	4	6
Mortality	2	-	1

x/ includes both PTC and PTD procedures

3.1. COMPLICATIONS OF RADIOLOGICAL PROCEDURES OBSERVED USING

3.1.1. Angiography (I)

At angiography intrahepatic vascular lesions were demonstrated in 27 out of 83 patients. In 14 patients, an aneurysm of the hepatic artery was detected, located in the right liver lobe in 13 patients and in the left liver lobe in one. Maximum aneurysm size was 2 x 3 cm. All aneurysms 1 cm or larger were located centrally, in the right liver lobe in 7 patients and in the left liver lobe in one.

In 7 patients, a non-opacified subcapsular area, measuring 1 - 3 x 2 - 10 cm, was found adjacent to the PTD catheter in the right lobe of the liver. These were regarded as haematomas.

A hepatic artery - portal vein fistula was found close to the drainage catheter in the right liver lobe in 6 patients. In 3 of these patients the fistula was situated peripherally and in the other 3 centrally. In one patient a hepatic artery - hepatic vein fistula was discovered adjacent to an aneurysm.

In 2 patients angiography was repeated, 6 weeks and 6 months, respectively, after the initial examination. Spontaneous closure of the lesions was demonstrated in both patients.

The platelet count was normal or slightly above normal in all patients. The APTT value was slightly elevated in 2 patients with complications and in 7 patients without vascular lesions.

Twenty-two of the 27 patients displayed no symptoms which could be attributed to vascular lesions. One patient with a hepatic artery - portal vein fistula developed marked haemo-

bilia and melaena. This patient was treated conservatively with blood transfusion. Extensive arterial bleeding into the drainage tract, in 4 patients with aneurysms located centrally in the right liver lobe, was stopped by embolising the hepatic artery with Gelfoam. Two of these patients died within 72 hours from hepatic failure.

### 3.1.2. Computed tomography (II)

CT revealed peripherally located hepatic lesions adjacent to the puncture site in 4 out of 23 examinations following PTD and in 4 out of 10 examinations following PTP. The median attenuation value of the lesions was 20 Hounsfield units (HU) lower (range 10 - 70) than that of the aorta, while the median value of the surrounding normal hepatic parenchyma was 10 HU (range 1 - 13) higher than that of the aorta. The existence of a lesion was confirmed surgically in one patient only. This patient had a large subphrenic collection of infected bile.

### 3.1.3. Cholangiography and clinical findings

#### 3.1.3.1. Percutaneous transhepatic cholangiography and drainage (III)

Radiologically detected complications at PTC/PTD were noted in 50/237 procedures (21 %) (Table 2).

Bile leakage was the most common complication. It was considered to have occurred when contrast medium was seen outside the liver. Haemobilia was seen as contrast filling defects caused by blood clots developing in the biliary tract during the examination. Displacement of the peripheral bile ducts, regarded as haematoma, was the only abnormality in 2 patients but was also seen together with bile leakage in one patient and haemobilia in another. In 2 patients the tip of the stainless steel guide-wire broke off inside the bile duct. No apparent harm befell the patients, however, and in

one the piece of guide-wire was successfully removed using an endoscope.

TABLE 2. Radiologically detected complications following 237 PTC/PTD procedures

Haemobilia	18
Haemobilia and liver haematoma	1
Haemobilia and peritonitis	2
Bile leakage	24
Bile leakage and liver haematoma	1
Liver haematoma	2
Broken guide-wire	2
	50 (21 %)

According to the patients' medical records, complications at PTC/PTD occurred in 26/237 procedures (11 %):

TABLE 3. Clinically detected complications following 237 PTC/PTD procedures

Peritonitis	6
Haemobilia	5
Pleurisy	3
Subphrenic abscess	2
Intraabdominal bile leakage	2
Intraabdominal bile leakage and bleeding	1
Intraabdominal bleeding	1
Sepsis	1
Aspiration	1
Myocardial ischaemia	1
Pneumothorax	1
Death	2
	26 (11 %)

Two patients (1 %), in poor general condition, died soon after the PTC/PTD procedure. Interventional procedures or blood transfusions were required as treatment in 15 patients, 6 percent of the total material.

The complication rate was positively correlated to the number of punctures with the sheathed PTC needle and to the examination time. Failure to insert the drainage catheter into the bile ducts was found to greatly increase the risk of complications. This occurred in 5/13 patients (38 %). Only one patient suffered a complication (pneumothorax) following an exclusively diagnostic fine needle PTC.

Among those patients in whom biliary drainage could be established, three groups were identified with respect to biliary infection. The combination of right upper quadrant pain, fever and/or leucocytosis was taken as indicating biliary infection. In the first group (65/184) biliary infection was not clinically evident before the drainage catheter was inserted. These patients remained asymptomatic after the examination. Bacterial culture was only performed in 5, all negative. In the second group (64/184), also initially asymptomatic, the patients developed signs of biliary infection after PTD. This was confirmed with a positive bile culture in 44 cases. The third group (55/184) had clinical signs of infection before the PTD procedure. Among these, clinical signs of infection disappeared after the procedure in 26 out of 55. However, the positive culture was obtained from all 10 bile samples taken from these 26 patients. Finally, signs of infection remained after PTD in 29 out of 55, confirmed with a positive culture in 12 out of 14.

The position of the tip of the drainage catheter was correlated to the frequency of positive bile cultures. Infected bile was registered in 61 percent of patients when the catheter tip was positioned above the obstruction, in 85 percent when it was positioned below and in 94 percent when it was positioned in the duodenum. Patients with two or more cathe-

ter adjustments exhibited an increased incidence of positive bile culture (10/12 = 83 %) compared with those in whom the catheter had been adjusted only once (19/46 = 41 %). The serum bilirubin level and the interval between admission and the PTC/PTD procedures were not found to influence the complication rate or the existence of bile infection.

#### 3.1.3.2. Preoperative intravenous infusion cholangiography (V)

At PIC only 2 minor (1 %), and no severe, reactions occurred. The maximum decrease in systolic blood pressure was 30 mm Hg. No patients experienced symptoms attributable to changes in blood pressure.

#### 3.1.3.3. Operative cholangiography (IV)

No complications were noted.

### 3.2. DIAGNOSTIC RESULTS OF CHOLANGIOGRAPHY (IV)

#### 3.2.1. Preoperative intravenous infusion cholangiography

PIC was considered normal in 74/91 patients (group 2). In 17 patients PIC was classified as pathological or inconclusive. These patients were then subjected to OC. In 9 patients OC confirmed calculi revealed at PIC. In another 2 patients, with no contrast medium visible at the preoperative examination, and thus classified as inconclusive, calculi were found at OC. In all these 11 patients, calculi were confirmed at subsequent exploration of the common bile duct. Of the remaining 6 patients calculi were excluded at OC in 5. In one patient OC supported the impression gained at PIC of a common bile duct calculus. The calculus was not found at choledochoscopy which, however, was performed after instrumental exploration of the common bile duct.



In one patient in group 2 PIC suggested distal fusion of the dorsocaudal branch of the right hepatic duct to the common hepatic duct. This finding was confirmed at OC.

### 3.2.2. Operative cholangiography

OC (group 1) failed in 2 patients due to difficulties in catheterising a very narrow cystic duct. The examination was considered to be normal in 82/94 patients and pathological in the remaining 12. In 9 of these 12 patients exploration of the common bile duct confirmed calculi in 7. In the other 2 patients OC suggested bile duct calculi but this could not be confirmed at choledochoscopy. The existence of a calculus could not be excluded in one of these patients - fibrinous sludge was found in a 13 mm wide common bile duct at choledochoscopy and PIC also indicated a common bile duct calculus. Of the remaining 3 patients one had a 15 mm wide common bile duct without calculi. In the other 2 patients OC indicated common bile duct calculus. However, in all these 3 patients, the gallbladder contained a solitary calculus and the cystic duct was very narrow. The operating surgeon did not consider the radiological findings to be compatible with calculi and the common bile duct was not explored.

An additional 13 OC's were carried out in group 2 because of findings at operation in 5 patients and due to surgeons not adhering to the protocol in another 8. Thus the diagnostic yield of OC and PIC could be compared in 124 patients (94 group 1 and 30 group 2) examined with both methods. In 110/124 patients (89 %) the radiopacity of the contrast medium in the bile ducts at PIC was considered to be sufficient for diagnosis. In 14 patients the PIC was considered inconclusive. A diagnostic accordancy was obtained in 97 patients and discordance in 27. Discordant results are shown in Table 4.

TABLE 4. Discordant diagnostic results in 27/124 patients examined with both PIC and OC. Evaluation based on radiographic comparison, operative findings and choledochoscopy

Patients No.	P I C	O C	Final judgement
14	Inconclusive	Normal	Normal
8	Susp. calculus	Normal	Normal
2	Normal	Calculus	Normal (solitary stone in gallbladder, narrow cystic duct, no exploration)
1	Normal	Calculus	Normal (exploration neg: performed before scopy)
1	Normal	Calculus	Calculus (chip fragment)
1	Calculus cystic duct	Calculus common duct	Calculus (displaced from cystic duct to common duct in between examinations)

#### 4. EXPERIMENTAL INVESTIGATION

As mentioned earlier, the percutaneous transhepatic route allows balloon catheter dilatation of bile duct strictures. Since little is known about the microscopic changes in the bile ducts caused by this procedure, an experimental model was set up to study the morphology of surgically created stenotic bile duct anastomoses in the pig, before and after transhepatic balloon catheter dilatation (IV).

##### 4.1. MATERIAL AND METHODS

##### 4.1.1. Creation of bile duct strictures

Under general anaesthesia, the common bile duct was exposed and divided transversely in 13 standard Swedish domestic

pigs. Triangular-shaped excisions were made from each free end of the divided duct. The defects were sutured and the ends anastomosed end-to-end over a catheter (OD 1.6 mm) with single, interrupted 4/0 chromic catgut sutures. The catheter, with its tip proximal to the anastomosis, was put through the right liver lobe and pulled subcutaneously to the back of the animal where it was attached to a drainage bag.

#### 4.1.2. Transhepatic cholangiography

The anastomoses were examined, using contrast medium injected through the drainage catheter, immediately postoperatively and again within 2 weeks of operation. Before balloon catheter dilatation and prior to sacrifice of the animals, radiological evaluations of the anastomoses were made using PTC.

#### 4.1.3. Balloon catheter dilatation

After PTC, the puncture catheter was exchanged over a guidewire for a 7F 6 x 20 mm balloon dilatation catheter in 2 animals and for a 6F 6 x 40 mm balloon dilatation catheter in 3 animals. Dilatation was accomplished, under fluoroscopic control, by manual inflation of the balloon using a 5 ml syringe for periods of 5 x 2 minutes and 3 - 5 x 1/2 minute, respectively.

#### 4.1.4. Histology

The common bile duct, duodenum and porta hepatis were removed and immersion-fixed in 10 percent formaldehyde solution. Several 4 micron sections were stained with haematoxylin-erythrosin and according to van Gieson.

## 4.2. RESULTS

### 4.2.1. Strictures not dilated by balloon catheters

One pig died one day postoperatively for unknown reasons and another pig died of multiple abscesses 2 weeks postoperatively. Six animals were sacrificed without previous balloon catheter dilatation 5 to 25 weeks after surgical creation of a bile duct stenosis. There was a remaining stenosis in all the animals at PTC before they were put to death. Microscopic examination of the stricture showed slight to moderate fibrosis of the bile duct wall which appeared to become more pronounced with time.

### 4.2.2. Strictures dilated by balloon catheters

Percutaneous transhepatic balloon catheter dilatation of the strictures was performed in 5 animals, 4 - 10 weeks postoperatively. An increase in stricture diameter of 2 - 3 mm (50- 100 %), as measured on the films, was achieved by the procedure. In no animal was the stricture completely eliminated. Two animals died within 5 days of dilatation. One pig died of bile leakage from the puncture site in the liver. The other pig developed a large right-sided bile pleurisy. Microscopy, in these animals, revealed necrosis of the bile duct mucosa. In one animal, a fresh tear into the bile duct wall was also noted as well as fresh thrombi in small peribiliary veins, necrotising pancreatitis and haemorrhagic liver necrosis. In the remaining 3 animals PTC, performed 4 - 6 weeks after dilatation and prior to sacrifice, revealed partial re-stenosis with reduction in the diameter of the stricture. Microscopic examination showed inflammatory reaction and fibrotic healing.

## 5. DISCUSSION

### 5.1. COMPLICATIONS OF PERCUTANEOUS TRANSHEPATIC PROCEDURES

#### 5.1.1. Vascular lesions

The aetiology of hepatic arteriovenous fistulae and aneurysms may be congenital or acquired i.e. arteriosclerotic, traumatic or inflammatory /14,18,25,67,83/ as well as neoplastic /74,134/. The vascular lesions observed in this investigation (I), were caused by the percutaneous transhepatic procedure since they were all situated near the drainage catheter.

Vascular complications following needle biopsy of the liver have been described in a number of reports /3,35,94,131,156,160/. Vascular lesions following PTC have also been reported. As one might expect, the frequency of vascular complications is dependent on technical factors such as needle thickness. OKUDA et coll /125/ found 2 arterioportal fistulae (2.5 %) and one fistula between the hepatic artery and hepatic vein (1.3 %) in 79 patients examined with angiography within one month after PTC using a fine needle (OD 0.7 mm). In one patient, who had been subjected to both biopsy and fine needle PTC, an aneurysm was demonstrated.

Vascular complications are more common using a crude needle. TYLEN et coll /157/ found arterioportal fistulae in 3/22 (14 %) patients following PTC, without biliary drainage, when using a catheter-sheathed needle (OD 1.6 mm) with a cutting edge. Somewhat fewer vascular complications were observed by MARIONS and WIECHEL /98/ in patients examined with angiography within 2 weeks following the transhepatic procedure. They found arterioportal fistulae in 6/89 (7 %) and spurious aneurysms in 3/89 (3 %) when using a slightly thinner catheter-sheathed mandrine (OD 1.45 mm) with a 60 degree bevelled, conic, non-cutting tip.

Following crude needle PTC and the introduction of a temporary or permanent draining catheter (OD 2.2 mm) into the bile ducts, TYLEN et coll /157/ noted arterioportal shunts in 3/43 (7 %) and small extravasations or false aneurysms in another 2/43 (4.7 %). MONDEN et coll /112/ at angiography 2-41 days following inception of biliary drainage, reported 4/47 (8.5 %) arterioportal shunts and pseudoaneurysms in 2/47 (4.3 %) when using a slightly thicker drainage catheter (OD 2.39 mm). The frequency of arterioportal shunts in our investigation (I) is in agreement with these findings. The reason for the higher frequency of false aneurysms in our study (14/83 = 17 %) is not clear. A possible explanation is that the investigation was initiated as a result of the occurrence of several haemorrhagic complications. The disparity in frequency of vascular complications could also be explained by differences in time lapse before angiography was performed. HELLEKANT and OLIN /75/ detected vascular injuries in 50 percent of punctured rabbit livers when angiography was performed immediately after puncture. In a clinical study, HELLEKANT /74/ noted that 11/18 (61 %) abnormalities due to puncture of the liver were demonstrated at angiography performed within one week and in only 3/27 (11 %) patients when angiography was performed later. These findings indicated rapid healing of the injuries. On the other hand, OKUDA et coll /125/, in a series of 26 patients catheterised for bile duct decompression or PTP with catheters up to 2.36 mm OD, observed arterioportal shunts in 19 percent and hepatic artery to hepatic vein fistulae in another 8 percent, at angiography performed 7-30 days after the procedure.

Mycotic arteritis secondary to chronic biliary infection is also a potential cause of pseudoaneurysm formation. In a study by MITCHELL et coll /109/ of haemobilia due to pseudoaneurysms and arterioportal shunts, in 17 patients with biliary drainage, 8 had cholangitis or sepsis.

In the present investigation (I), the large size of the aneurysms, and also their central location, is remarkable. It is reasonable to expect that a vessel punctured centrally in the liver is more likely to develop complications than a vessel in the periphery, if only because of its larger diameter and higher vascular pressure. To reduce the risk of vascular complications, and to allow for a long intraductal track, insertion of the drainage catheter in a peripheral bile duct has been suggested /77,112,125/.

A wide arterioportal shunt may cause portal hypertension /57/. A persistent fistula between the hepatic artery and the hepatic vein may result in cardiac failure /160/. However, puncture-induced arteriovenous fistulae tend to close spontaneously. This has been shown in the kidney /46/ and in the liver /65,74/. Spontaneous closure of arteriovenous fistulae in our investigation was observed in the only 2 patients examined with follow-up angiography (I).

A correlation could not be found in our investigation between the coagulation factors registered and the occurrence of vascular lesions (I). A similar lack of correlation has been reported by others /22,65,112,157/.

Haemobilia was the second most common complication (9 %; III) and occurred more frequently after insertion of the drainage catheter - the side holes allow blood to enter the biliary tract at insertion. Usually this is of little clinical significance, the bleeding ceasing spontaneously - probably because of the decreased size of the liver after biliary decompression /22/. To prevent catheter dislodgement and malfunction careful surveillance is essential.

Massive bleeding into the drainage tract, diagnosed at angiography, occurred in 5 patients (I). One patient, with an arterioportal shunt, was treated with transfusion only. The other 4 patients, who had aneurysms measuring 1.5 to 3 cm, adjacent to the drainage tract, were subjected to embolisa-

tion of the hepatic artery using Gelfoam. Unfortunately, selective occlusion of the damaged vessel failed with the result that almost the entire hepatic arterial supply was cut off. Two of the patients died from liver failure within 72 hours but the treatment was successful in the other 2. Based on results obtained from experimental studies in the monkey, DOPPMAN et coll /40/ have drawn attention to the risk following embolisation of the hepatic artery in the presence of obstructive jaundice. They found that embolisation caused massive hepatic necrosis probably as a result of the decreased portal venous inflow which is a feature of biliary obstruction.

Transcatheter arterial embolic control of haemobilia following liver biopsy has been reported by WALTER et coll /162/ and PERLBERGER /129/. Hepatic artery embolotherapy for severe haemobilia associated with percutaneous catheters has been reported by others /44,81,101,137/. To control bleeding, different material such as bucrylate, Gelfoam and coils have been used. MITCHELL et coll /109/ preferred detachable balloons because of their ability to exclude the injured portion of the artery from inadvertent distal embolisation and risk of recanalisation. They used this technique successfully in 12/13 patients with haemobilia. Embolotherapy of an hepatic artery pseudoaneurysm via the transhepatic tract has been described in one patient /137/.

#### 5.1.2. Parenchymatous lesions

Hepatic lesions were demonstrated with CT in 4 patients following 23 PTD procedures (II). All the lesions were located peripherally, adjacent to the puncture site, and all were discovered within 5 to 10 days of the transhepatic procedure. The attenuation values were lower than that of the surrounding liver parenchyma but the nature of the lesions was not determined conclusively except in one patient who proved to have an extrahepatic collection of infected bile at sur-



gery. This was also the only patient with symptoms referable to the transhepatic procedure.

The incidence of parenchymatous hepatic lesions, observed radiologically, was 17 percent at CT (II), 8 percent at angiography (I) and only 2 percent at cholangiography (III), indicating the superiority of CT in detecting avascular parenchymal lesions. Other diagnostic modalities such as nuclear scanning /133/ and ultrasonography /56/ have been used to detect hepatic lesions following liver biopsy. Occasional liver haematomas have been discovered at ultrasonography following fine needle PTC /70/.

#### 5.1.3. Clinical complications

When non-invasive methods were still not available for evaluation of intrahepatic lesions, most complications at PTC were revealed at subsequent laparotomy. Leakage of bile or blood into the peritoneal cavity was thus observed by SELDINGER /143/ in 15/96 (15.6 %) patients and 4/96 (4.2 %) patients, respectively. The corresponding figures from GÖTHLIN and TRANBERG /65/ were 4/47 (8.5 %) and 4/47 (8.5 %), respectively. All patients but 2 (SELDINGER's material) had dilated bile ducts. All the procedures were performed with crude needles and without drainage.

Following fine needle PTC, intraperitoneal bile leakage was noted at surgery in 1.45 percent of patients with dilated bile ducts /70/. In one third of these patients leakage of small amounts of bile caused no symptoms and was an incidental finding at laparotomy. Although the onset of generalised bile peritonitis is usually sudden, the cause may be indolent and the patient may present with progressive ascites /136/. In our investigation (III), accumulation of contrast medium outside the liver, following PTC and drainage, was taken as evidence of bile leakage. This was seen in 24 cases at cholangiography but symptoms of bile leakage was clinically registered in only 8.

Leakage of bile or blood is very frequent when the radiologist fails to introduce a drainage catheter into dilated bile ducts (III). Stepwise withdrawal of the needle /98/ or injection of occlusive material into the puncture tract /77/ has been suggested to reduce the risk of leakage of bile or blood to the abdominal cavity.

Puncture related complications may be reduced using fine needle coaxial catheter introductory instruments /5,30,73/.

Infection is a common finding in the biliary tract /52,85/. According to KEIGHLEY et coll /85/, and KEIGHLEY /84/, infected bile, collected at operation, occurs in 71 to 90 percent of patients with common bile duct calculi and 25 to 36 percent of patients with tumour obstruction. The most common organisms were E-coli and Klebsiella. Similar results were obtained at percutaneous transhepatic biliary sampling by SUZUKI et coll /149/ who also found a high frequency of the same organisms in the duodenum. These findings favour the hypothesis of an ascending infection. Haematogeneous /38, 141/ and lymphogeneous /170/ transport have also been suggested, but the exact route is not certain /151/. Most authors recommend prophylactic use of antibiotics before direct cholangiographic procedures /16,52,70,103/. In biliary obstruction, the level of antibiotics in the bile is low and, to reduce septic complications, adequate serum levels of an effective antimicrobial is more important than an antibiotic which is excreted almost entirely into the bile /86/. The use of prophylactic antibiotics does not prevent the often fatal but rare event of endotoxic shock /70/.

In our investigation (III) one third of the patients showed no clinical signs of infection before or after insertion of a drainage catheter. One third of the patients developed clinical signs of biliary infection following the drainage procedure and one third of the patients had clinical evidence of biliary tract infection before PTC. In this last group, signs of infection persisted or disappeared in an

equal number of patients. Only one septic (fever, hypotension, positive blood culture, chills and prostration) complication was noted.

Several authors consider infection a major problem in transhepatic drainage /23,51,69,103/. At least to some degree the infections are exogenous in origin /103,114/ and could be reduced with a closed drainage system /15,16,103/. Connecting the catheter to a subcutaneously positioned reservoir has also been used in an attempt to decrease the risk of exogenous infection /45,159/.

On the other hand, in patients with sepsis due to cholangitis and biliary obstruction, drainage through an indwelling catheter often has a dramatic effect on the patient's clinical condition /50,66,82,117/ and should be the treatment of choice.

The catheter tip positioned in the distal common bile duct rather than in the duodenum seems to reduce bile infections /103/. This is supported by our findings (III) - patients with a transampullary drainage catheter produced a positive bile culture in 94 percent whereas patients with the catheter placed proximal to the sphincter or above the obstruction produced a positive bile culture in 85 percent and 61 percent, respectively. The validity of these findings was not statistically confirmed.

Rare complications at PTC and drainage are bile emboli /11/, drainage tract metastases /36,77,87,126,146/, duodenal perforation /36/ and rib erosion /144/.

One case of pneumothorax and 3 cases of pleurisy could probably have been avoided if the liver had been punctured below the 10th rib /118,119/.

PTC and drainage is a widely accepted efficient method of reducing elevated bilirubin levels in obstructive jaundice /77,117,127,166/. Considerable controversy still remains as

to whether or not preoperative decompression of the obstructed bile ducts reduces operative mortality (all deaths within 30 days postoperatively). TAKADA et coll /150/ and NAKAYAMA et coll /117/ reported a decrease in operative mortality from 28 percent to 7 percent and from 24 percent to 8 percent, respectively, in two retrospective studies where patients with preoperative transhepatic drainage were compared with historic controls. Similar results were obtained by GOBIEN et coll /62/ and GUNDRY et coll /68/. DENNING et coll /37/ found a significant reduction in operative morbidity and a decreased, but not statistically significantly decreased, operative mortality. On the other hand, in randomised studies, HATFIELD et coll /72/ found no difference and McPHERSON et coll /104/ and PITT et coll /130/ found increased operative mortality in patients with preoperative transhepatic drainage as compared to in non-drained patients. These data are difficult to evaluate. In HATFIELD et coll's study, one death in the transhepatic drainage/surgery group occurred following technical failure of the drainage catheter, while 2 deaths occurred following unjustified surgery. In the surgery alone group, 2 deaths actually occurred prior to surgery and one patient, in spite of the fact that he was assigned to this group, also underwent drainage. In McPHERSON et coll's study /104/, 5 patients allocated to the preoperative drainage group died before operation. A point of interest in the Japanese studies /117,150/ is the comment on re-feeding of bile. This was also pointed out by NORLANDER et coll /120/ who found a reduction in the operative mortality in the preoperatively drained group when patients with inefficient drainage were excluded. They reported that bilirubin levels did not return to normal unless bile was re-fed to the intestine. The impairment of renal function which occurs with obstructive jaundice is ascribed to the inability of the liver to detoxify endotoxin which has gained access to the portal circulation from the gut /2,169/. This process is normally inhibited by the presence of bile salts in the intestinal lumen /10,68,130/. KOYAMA et coll /89/ have demonstrated severe depression of hepatic function,

especially mitochondrial energy production, one to 2 weeks after total obstruction. They also found that these processes may take 6 weeks or more to improve following relief of obstruction. Other investigators /130/ have documented depressed cell-mediated immunity, impaired hepatic reticuloendothelial function and altered lymphocyte transformation in patients with obstructive jaundice. These data strongly suggest the desirability of a prompt atraumatic restoration of the passage of bile to the intestine for a period of time long enough for the liver to recuperate before surgery.

Most patients with malignant biliary obstruction, however, will never be candidates for attempts at curative surgery since resectability can only be expected in 7 to 14 percent /4,127/.

Transhepatic or endoscopic insertion of endoprosthesis as well as operative biliary diversion are alternatives to catheter drainage in palliation of patients with malignant biliary obstruction.

Insertion of an endoprosthesis, via the PTC tract, for palliative internal drainage in patients with incurable biliary obstruction was practised by WIECHEL /166/ and was widely in use at the end of the 70's and beginning of the 80's /19,20, 28,78/. Leakage, migration, incrustation and infections are the most frequent complications. Early complications are reported to occur in from 5.5 percent /19/ to 17 percent /115/ and late complications in from 5.7 percent /19/ to 31 percent /115/. In a review of the literature on the results of biliary drainage, using endoprosthesis in 552 patients and catheters in 360, LAMMER /91/ found a complication rate of 13 percent, a procedure mortality of 1.3 percent and an operative mortality of 24 percent at endoprosthetic drainage. The corresponding figures at catheter drainage were 11 percent, 1.6 percent and 15 percent. The use of endoprosthesis has been shown to correlate positively with short-term survival rate up to 6 months, but not thereafter, when compared with drainage catheters /127/. On the other hand, some authors find drawbacks of endoprosthesis too numerous and have

suggested the method be abandoned /107/. Endoprosthesis is, despite its drawbacks, an alternative for patients who cannot tolerate an external catheter /29/.

In recent years endoscopic biliary drainage has become an alternative to the transhepatic route /24,31,80,99,148/. Insertion of a bilio-nasal drain or a bilio-duodenal endoprosthesis are successful in 95 percent and 87 percent, respectively /24/. Cholangitis is the most frequent complication and in large series the total complication rate varies between 5 percent and 26 percent and the mortality rate varies between 0.7 and 8 percent, depending on the technique used and on the experience of the operator /24,135/.

The complication rate of transhepatic or endoscopic biliary drainage should be compared to a reported mortality of 16 to 40 percent /55,161,49/. Ultimately, in patients with malignant obstruction of the biliary tract with a median life expectancy of only 3 months /127/, much attention should be paid to quality of life.

## 5.2. PREOPERATIVE INTRAVENOUS INFUSION CHOLANGIOGRAPHY AND OPERATIVE CHOLANGIOGRAPHY

### 5.2.1. Diagnostic efficacy

Since MIRIZZI introduced OC in 1932 /108/ its value has been extensively explored /9,32,43,95,121/. The benefits of routine OC are widely recognised and the procedure is performed routinely in 96 percent of the surgical units in Sweden /13/. The drawbacks of the method are delay in obtaining diagnostic information and the occasionally time consuming radiographic procedure leading to an increase in operating time. The advantages of OC are the reported low incidence of diagnostic misinterpretations. In a large retrospective series LINDSKOG /95/ found calculi to be overdiagnosed in 0.4 percent and underdiagnosed in 0.026 percent. In the endo-

scopic era a retained calculus does not constitute the predicament it used to, since transpapillary stone extraction is now an alternative to re-operation. The endoscopic procedure, however, is not harmless and complication rates from 7.0 percent to 8.7 percent /59,139/ and mortality rates from 1.02 percent to 1.4 percent /59,139,142/ have been reported. Overdiagnosing a bile duct calculus, leading as it does to an unnecessary choledochotomy, causes a mortality rate from 1.8 percent to 3.5 percent /60,105/.

PIC gives preoperative information which allows planning of tactics to be employed during operation. This is not possible with OC, as pointed out by WIECHEL and MARIONS /168/. In fact the biliary system seems to be one of the few systems on which surgeons are willing to operate without having any preoperative morphological information. PIC is also positively correlated to a significant reduction in operating time, as noted in our investigation (IV). The image quality of PIC is lower than that of OC. This is due to technical factors and to dependence on hepatic function. The intrahepatic ducts in particular are not very well delineated. This could lead to an increased risk of underdiagnosing bile duct calculi and bile duct anomalies. In our investigation (IV) one case of low fusion of the dorsocaudal branch of the right hepatic duct to the common hepatic duct was noted at PIC. This finding was confirmed at OC. No operative bile duct injuries were disclosed in our series.

PIC's were classified as diagnostic in 89 percent which is in agreement with the results obtained in other studies using iotroxate /41,154/. The high diagnostic yield in our investigation is in accordance with a recent retrospective study /64/. The low diagnostic yield reported by others /63, 48/ could be explained by the fact that these studies included unselected patients with elevated bilirubin values and liver enzyme abnormalities, whereas in our investigation all patients apart from 3 had normal bilirubin values. Our investigation was performed with a modern cholangiographic

contrast medium giving higher contrast medium concentration in the bile ducts.

The administration of a sphincter relaxing drug, e.g. glucagon, would probably have eased the task of differentiating between spasm of the sphincter of Oddi and a calculus in the distal part of the duct in some OC's /17/. Likewise more PIC's would have been diagnostic had disturbing motion of the duodenum been inhibited by an anticholinergic drug.

In the follow-up study, now close to 5 years, no residual stones have been detected.

#### 5.2.2. Complications

The mortality at intravenous cholangiography varies in the literature from 1/5000 /6/ to 1/50 000 /155/. There is also a disparity in the incidence of adverse reactions at intravenous cholangiography in different reports. It is generally agreed, however, that intravenous cholangiography is more toxic than urography /6,7,145,155/. In a recent prospective investigation of adverse reactions to contrast media in more than 300 000 cases /145/, the rate of reactions was almost twice as high at intravenous cholangiography as it was at urography - 8.0 percent and 4.8 percent, respectively. That investigation was an international multicentre study, not specifying the type and dose of contrast media used or the mode of administration. In our investigation (V) the incidence of adverse reactions to infusion cholangiography with iotroxate was low. Only two minor (1 %) and no severe reactions were noted. In the review of the clinical literature on adverse reactions to iotroxate in 2492 patients (including those in our own investigation), the average complication rate at infusion was 3.5 percent (3.0 % minor, 0.3 moderate and 0.2 % severe reactions). This compared favourably with the 5 percent complication rate (4 % minor, 0.5 % moderate and 0.5 % severe reactions) at infusion of iodoxamate and the 9 percent complication rate (5 % minor, 1 % moderate



and 3 % severe reactions) at infusion of ioglycamide revealed in the same review. Irrespective of the contrast medium used, the frequency of adverse reactions at infusion was found to be 3 times lower than when equal amounts of the same medium were injected. This concurs with the findings in several previous reports that infusion is an important factor in reducing adverse reactions to intravenous cholangiography /34,41,102/. In our investigation the patients were selected and well hydrated which probably contributed to the low complication rate.

A fatal reaction to ioglycamide in a patient with Waldenström's monoclonal IgM paraproteinaemia /12/ has been reported and one fatal and one severe reaction to ioglycamide have been observed in patients with lymphoproliferative disorders /88/. Although no definite conclusions can be drawn about the use of iotroxate in these conditions, these disorders should be regarded as an absolute contraindication to intravenous cholangiography.

Complications to OC is reportedly low. LINDSKOG /95/, in a review of 4685 patients subjected to cholecystectomy preceded by operative cholangiography, could not find any complications directly referable to the radiographic procedure. WHITE and HART /164/, however, in a series of 18 patients with bile duct injuries, found these to be caused by attempts to perform an operative cholangiography in 8 patients, all of whom had bile ducts 3 mm in diameter or less and a tiny cystic duct.

Diagnostic and other benefits can be expected from digital technology applied to operative fluorocholangiography /54/ and intravenous cholangiography /153/.

### 5.3. EXPERIMENTAL BILE DUCT STRICTURES

Benign strictures of the biliary tract are reported to recur in 25 to 35 percent following reconstructive surgery /61,

163/. Promising clinical results have been achieved with transhepatic balloon catheter dilatation of biliary strictures /58,140,152,158/. Although the long-term results using this technique are not known it has the advantage over surgery that a re-dilatation is easily performed. An experimental model was set up in the pig to study the immediate and short-term morphological changes in surgically created fibrous stenotic anastomoses before and after transhepatic balloon catheter dilatation. Those anastomoses which were not subjected to balloon dilatation displayed a persistent stricture at cholangiography and slight to moderate fibrosis at microscopy during 25 weeks postoperative follow-up (VI).

Balloon catheter dilatation caused a lesion in the bile duct wall which was followed by fibrous healing. In the short-term follow-up a relative re-stenosis was noted. The technique is not harmless, which is illustrated by serious complications in 2 pigs. Both died within 5 days of balloon dilatation, probably due to bile leakage from the puncture site. A number of procedure related questions, e.g. optimal duration of dilatation and stenting, remain to be answered. The pig, due to its rapid growth, is not the ideal animal for this purpose. The technical problems of gaining access to the bile ducts, which could be expected in a smaller species, could be overcome by performing the dilatation through a stomatised jejunal limb according to RUSSELL /138/.

## 6. C O N C L U S I O N S

- Vascular, parenchymatous and infectious complications at PTC and drainage of the bile ducts were frequent findings in three retrospective investigations using angiography, CT and PTC as well as clinical evaluation. The number of complications, requiring treatment, was acceptably low and comparable to the number of complications at endoscopic and operative drainage as reported in the literature.

- Preoperative intravenous infusion cholangiography with iotroxate, before elective cholecystectomy, resulted in a high diagnostic yield and a low incidence of adverse reactions. Preoperative intravenous infusion cholangiography with iotroxate, supplemented with operative cholangiography in inconclusive cases, is an alternative to routine operative cholangiography and was found to reduce operating time significantly.

Results from the present investigation and a review of the literature showed a low average incidence of complications to intravenous infusion cholangiography with iotroxate, not exceeding the complication rate reported with ionic urographic contrast media.

- Surgically created fibrous stenoses in common bile duct anastomoses in the pig persisted during a follow-up period of 25 weeks. Percutaneous transhepatic balloon catheter dilatation of the stenotic area caused a bile duct wall lesion which resulted in fibrous healing which was almost complete after 4 weeks. An initial increase of the stricture diameter was followed by partial re-stenosis in the short-term follow-up.

7. R E F E R E N C E S

1. ALLEN M., BORODY T., BUGLIOSI T., MAY G., LaRUSSO N. and THISTLE J.: Cholelithiolysis using methyl tertiary butyl ether. *Gastroenterology* 88 (1985), 122
2. ALLISON M., PRENTICE C. and KENNEDY A.: Renal function and other factors in obstructive jaundice. *Brit J Surg* 66 (1979), 392
3. ALMEN T. and NYLANDER G.: Intrahepatische arteriovenöse Fistel nach Leberbiopsie. *Fortschr Röntgenstr* 111 (1969), 292
4. ANDREN-SANDBERG Å. and IHSE I.: Factors influencing survival after total pancreatectomy in patients with pancreatic cancer. *Ann Surg* 198 (1983), 605
5. ANDREWS R. and HAWKINS I.: The Hawkins needle guide system for percutaneous catheterization: I. Instrumentation and procedure. II. Clinical experience in biliary tract and abscess drainage. *Amer J Roentgenol* 142 (1984), 1191
6. ANSELL G.: Adverse reactions to contrast agents. Scope of problem. *Invest Radiol* 6 (1970), 374
7. ANSELL G., TWEEDIE M., WEST C., PRICE EVANS D. and COUCH L.: The current status of reactions to intravenous contrast media. *Invest Radiol* 15 (1980), 32
8. ARIYAMA J., SHIRAKABE H., OHASHI K. and ROBERTS G.: Experience with percutaneous transhepatic cholangiography using the Japanese needle. *Gastrointest Radiol* 2 (1978), 359
9. ARNOLD D.J.: 28621 cholecystectomies in Ohio: Results of a survey in Ohio hospitals by the gallbladder survey committee. *Amer J Surg* 119 (1970), 714
10. BAILEY M.: Endotoxin, bile salts and renal function in obstructive jaundice. *Brit J Surg* 63 (1976), 774
11. BALOGH K.: Pulmonary bile emboli. Sequelae of traumatic ic trauma. *Arch Pathol Lab Med* 108 (1984), 814
12. BAUER K., TRAGE K. and BAUER G.: Intravasale Denaturierung von Plasmaproteinen bei einer IgM-Paraproteinämie, ausgelöst durch ein intravenös verabreichtes lebergängiges Röntgenkontrastmittel. *Wien Klin Wochenschr* 86 (1974), 766

13. BENGMARK S., LILJEDAHN S-O., SCHERSTEN T., SMEDBY B., STERKY G. and WEDEL H.: Vårdtidens längd vid gallstensoperation. Läkartidningen 76 (1979), 3989 (In Swedish)
14. BERNER C., COX E. and BUXTON R.: Unusual arteriovenous fistulas involving hepatic artery, portal vein and internal iliac vessels: Case report and a review of the literature. Amer Surg 33 (1967), 276
15. BLENKHARN J., McPHERSON G. and BLUMGART L.: An improved system for external biliary drainage. Lancet 2 (1981), 781
16. BLENKHARN J., McPHERSON G. and BLUMGART L.: Septic complications of percutaneous transhepatic biliary drainage: Evaluation of a new closed drainage system. Amer J Surg 147 (1984), 318
17. BORDLEY J. and OLSON J.: The use of glucagon in operative cholangiography. Surg Gynecol Obstet 149 (1979), 583
18. BROWNING L.D., CLAUSS R.H. and MacFEE W.F.: Aneurysm of the hepatic artery: Report of two cases. Ann Surg 150 (1959), 320
19. BURCHARTH F.: Experience with percutaneous biliary drainage. Ann Radiol 29 (1986), 135
20. BURCHARTH F., INGEMANN-JENSEN L. and OLESEN K.: Endoprosthesis for internal drainage of the biliary tract. Gastroenterology 77 (1979), 133
21. BURHENNE H.J. and MORRIS C.: Biliary stricture dilatation: Use of the Grüntzig balloon catheter. J Ass Can Radiol 31 (1980), 196
22. CAHOW C., BURRELL M. and GRECO R.: Hemobilia following percutaneous transhepatic cholangiography. Ann Surg 185 (1977), 235
23. CARRASCO H., ZORNOZA J. and BECHTEL W.: Malignant biliary obstruction: Complications of percutaneous biliary drainage. Radiology 152 (1984), 343
24. CLASSEN M. and HAGENMÜLLER F.: Endoscopic biliary drainage. Scand J Gastroenterol 19 (1984), 76
25. CLEAVELAND R., JACKSON M., NEWMAN P. and NELSON R.: Traumatic intrahepatic artery-portal vein fistula with associated hemobilia. Ann Surg 171 (1970), 451
26. CLOUSE M.: Dormia basket modifications for percutaneous transhepatic common bile duct stone removal. Amer J Roentgenol 140 (1983), 395

27. CONROY R., SHABAZIAN A., EDWARDS K., MORAN E., SWINGLE K., LEWIS G. and PRIBRAM H.: A new method for treating carcinomatous biliary obstruction with intracatheter Radium. *Cancer* 49 (1982), 1321
28. COONS H. and CAREY P.: Large-bore, long biliary endoprosthesis (biliary stents) for improved drainage. *Radiology* 148 (1983), 89
29. COONS H. and CAREY P.: Biliary endoprosthesis: Yes or no? *Amer J Roentgenol* 145 (1985), 429
30. COPE C.: Stiff fine-needle guide wire for catheterization and drainage. *Radiology* 147 (1983), 264
31. COTTON P.B.: Duodenoscopic placement of biliary prostheses to relieve malignant obstructive jaundice. *Brit J Surg* 69 (1982), 501
32. CRANLEY B. and LOGAN H.: Exploration of the common bile duct - the relevance of the clinical picture and the importance of preoperative cholangiography. *Brit J Surg* 67 (1980), 869
33. CROPPER L. and GOLD R.: Simplified brush biopsy of the bile ducts. *Radiology* 148 (1983), 307
34. DARNBOROUGH A. and GEFFEN N.: Drip infusion cholangiography. *Brit J Radiol* 39 (1966), 827
35. DEBRAY C., LEYMARIOS J., MARTIN E., HERNANDEZ C., CARAYON J. and COSTE F.: Fistules arterio-veineuses hepatoportales consecutives a une ponction-biopsie du foie. *Pr Med* 76 (1968), 737
36. DEMAS B., MOSS A. and GOLDBERG H.: Computed tomographic diagnosis of complications of transhepatic cholangiography and percutaneous biliary drainage. *Gastrointest Radiol* 9 (1984), 219
37. DENNING D., ELLISON C. and CAREY L.: Preoperative percutaneous transhepatic biliary decompression lowers operative morbidity in patients with obstructive jaundice. *Amer J Surg* 141 (1981), 61
38. DINEEN P.: The importance of the route of infection in experimental biliary tract obstruction. *Surg Gynecol Obstet* 119 (1964), 1001
39. DOOLEY J., IRVING R., OLNEY J. and SHERLOCK S.: Relief of bile duct obstruction by the percutaneous transhepatic insertion of an endoprosthesis. *Clin Radiol* 32 (1981), 163

40. DOPPMAN J., GIRTON M. and VERMESS M.: The risk of hepatic artery embolization in the presence of obstructive jaundice. *Radiology* 143 (1982), 37
41. DORAN J., CLIFFORD K., MARTIN P., KNAPP D. and BELL G.: Drip infusion cholangiography using iotroxamide. Double blind comparison with ioglycamide. *Brit J Radiol* 53 (1980), 654
42. DOTTER C., BILBAO M. and KATON R.: Percutaneous transhepatic gallstone removal by needle tract. *Radiology* 133 (1979), 242
43. DOYLE P.J., WARD-McQUAID J.N. and MCEWEN SMITH A.: The value of routine preoperative cholangiography - a report of 4000 cholecystectomies. *Brit J Surg* 69 (1982), 617
44. DRUY E.: Hepatic artery-biliary fistula following percutaneous transhepatic biliary drainage. *Radiology* 141 (1981), 369
45. EIBL-EIBESFELDT B.: Palliative internal bile drainage using percutaneous transhepatic drainage connected with subcutaneous implanted access chamber (Implanted PTC-drainage). In: *Proc 1st World Congr Hepato-Pancreatico-Biliary Surgery, Lund (1986)*
46. EKELUND L.: Spontaneous closure of arteriovenous fistulae following percutaneous renal biopsy. An experimental investigation in the rabbit. *Acta Radiol Diagnosis* 11 (1971), 289
47. ELYADERANI M.K. and GABRIELLE O.F.: Brush and forceps biopsy of biliary ducts via percutaneous transhepatic catheterization. *Radiology* 135 (1980), 777
48. EUBANKS B., MARTINEZ C., MEHIGAN D. and CAMERON J.: Current role of intravenous cholangiography. *Amer J Surg* 143 (1982), 731
49. FEDUSKA N., DENT T. and LINDENAUER M.: Results of palliative operations for carcinoma of the pancreas. *Arch Surg* 103 (1971), 330
50. FERRUCCI J., MUELLER P. and HARBIN W.: Percutaneous transhepatic biliary drainage. Technique, results and applications. *Radiology* 135 (1980), 1
51. FERRUCCI J. and MUELLER P.: Interventional radiology of the biliary tract. *Gastroentgenology* 82 (1982), 974
52. FLEMMER R., FLINT L., OSTERHOUT S. and SHINGLETON W.: Bacteriologic studies of biliary tract infection. *Ann Surg* 166 (1967), 563-572

53. FLETCHER M., BRINKLEY D., DAWSON J., NUNNERLY H., WHEELER P. and WILLIAMS R.: Treatment of high bileduct carcinoma by internal radiotherapy with Iridium-192 wire. *Lancet* 25 (1981), 172
54. FORK F-T., NYLANDER G. and OLIN T.: Bilateral videosingnalkommunikation mellan kir.op. och röntgenavd. med digital röntgenbildbehandling i samband med preoperativa röntgenundersökningar, MAS., Malmö. *Scand Radiol Soc (Proc 41st Congr)* (1983) (In Swedish)
55. FORREST J.F. and LONGMIRE W.P.: Carcinoma of the pancreas and periampullary region. *Ann Surg* 189 (1979), 129
56. FORSBERG L.: Personal communication (1986)
57. FOSTER J. and SANDBLOM P.: Portal hypertension secondary to an hepato-portal arterio-venous fistula. *Ann Surg* 154 (1961), 300
58. GALLACHER D., KADIR S., KAUFMAN S., MITCHELL S., KIN-NISON M., CHANG R., ADAMS P., WHITE R. and CAMERON J.: Nonoperative management of benign postoperative biliary strictures. *Radiology* 156 (1985), 625
59. GEENEN J., TOULI J., HOGAN W., DODDS W., STEWART E., MAVRELIS P., RIEDEL D. and VENU R.: Endoscopic sphincterotomy: Follow-up evaluation of effects on the sphincter of Oddi. *Gastroenterology* 87 (1984), 754
60. GIRARD R.M. and LEGROS G.: Retained and recurrent bile duct stones. Surgical or non-surgical removal. *Ann Surg* 193 (1981), 150
61. GLENN F.: Iatrogenic injuries to the biliary ductal system. *Surg Gynecol Obstet* 146 (1978), 430
62. GOBIEN R., STANLEY J., SOUCEK C., ANDERSON M., VUJIC I. and GOBIEN B.: Routine preoperative biliary drainage: Effect on management of obstructive jaundice. *Radiology* 152 (1984), 353
63. GOODMAN M., ANSEL H., VENNES J., LASSER R. and SILVIS S.: Is intravenous cholangiography still useful? *Gastroenterology* 79 (1980), 642
64. GÖRANSSON A-M.: Cholegraphy: Its application and reliability in connection with gall-stone operations. *Acta Chir Scand Suppl No. 496* (1980), 1
65. GÖTHLIN J. and TRANBERG K-G.: Complications of percutaneous transhepatic cholangiography (PTC). *Amer J Roentgenol* 117 (1973), 426



66. GOULD R., VOGELZANG R., NEIMAN H., PEARL G. and POTICHA S.: Percutaneous biliary drainage as an initial therapy in sepsis of the biliary tract. *Surg Gynecol Obstet* 160 (1985), 523
67. GRANT R., GLIEDMAN M. and DETERLING Jr R.: Coexisting traumatic arteriovenous fistulas between the aorta and vena cava and the hepatic artery and portal vein complicated by a "Goldblatt" kidney. *Ann Surg* 148 (1958), 286
68. GUNDRY S., STRODEL W., KNOL J., ECKHAUSER F. and THOMPSON N.: Efficacy of preoperative biliary tract decompression in patients with obstructive jaundice. *Arch Surg* 119 (1984), 703
69. HANSSON J., HOEVELS J., SIMERT G., TYLEN U. and VANG J.: Clinical aspects of nonsurgical percutaneous transhepatic bile drainage in obstructive lesions of the extrahepatic bile ducts. *Ann Surg* 189 (1979), 58
70. HARBIN W., MUELLER P. and FERRUCCI J.: Transhepatic cholangiography: Complications and use patterns of the fine-needle technique. *Radiology* 135 (1980), 15
71. HARELL G., ANDERSON M. and BERRY P.: Cytologic bile examination in the diagnosis of biliary duct neoplastic strictures. *Amer J Roentgenol* 137 (1981), 1123
72. HATFIELD A.R.W., TERBLANCHE J., FATAAR S., KERNOFF L., TOBIAS R., GIRDWOOD A.H., HARRIES-JONES R. and MARKS I.N.: Preoperative external biliary drainage in obstructive jaundice. A prospective controlled clinical trial. *Lancet* 2 (1982), 896
73. HAWKINS Jr I.: New fine needle for cholangiography with optional sheath for decompression. *Radiology* 131 (1979) 252
74. HELLEKANT C.: Vascular complications following needle puncture of the liver. *Clinical angiography. Acta Radiol Diagnosis* 17 (1976), 209
75. HELLEKANT C. and OLIN T.: Vascular complications following needle puncture of the liver. An angiographic investigation in the rabbit. *Acta Radiol Diagnosis* 14 (1973), 577
76. HERSKOVIC A., HEASTON D., ENGLER M., FISHBURN R., JONES S. and NOELL K.: Irradiation of biliary carcinoma. *Radiology* 139 (1981), 219
77. HOEVELS J., LUNDERQUIST A. and IHSE I.: Percutaneous transhepatic intubation of bile ducts for combined internal-external drainage in preoperative and palliative

- treatment of obstructive jaundice. *Gastrointest Radiol* 3 (1978), 23
78. HOEVELS J. and IHSE I.: Percutaneous transhepatic insertion of a permanent endoprosthesis in obstructive lesions of the extrahepatic bile ducts. *Gastrointest Radiol* 4 (1979), 367
  79. HOFMAN A., SCHMACK B., THISTLE J. and BABAYAN V.: Clinical experience with monoctanoïn for dissolution of bile duct stones: An uncontrolled multicenter trial. *Dig Dis Sci* 26 (1981), 954
  80. HUIBREGTSE K. and TYTGAT G.: Palliative treatment of obstructive jaundice by transpapillary introduction of large bore bile duct endoprosthesis. Experience in 45 patients. *Gut* 23 (1982), 371
  81. KADIR S., ATHANSOULIS C., RING E. and GREENFIELD A.: Transcatheter embolization of intrahepatic arterial aneurysms. *Radiology* 134 (1980), 335
  82. KADIR S., BAASSIRI A., BARTH K., KAUFMAN S., CAMERON J. and WHITE Jr R.: Percutaneous biliary drainage in the management of biliary sepsis. *Amer J Roentgenol* 138 (1982), 25
  83. KATZ M. and MENG C.H.: Angiographic evaluation of traumatic intrahepatic pseudoaneurysm and hemobilia. *Radiology* 94 (1970), 95
  84. KEIGHLEY M.: Micro-organisms in the bile: A preventable cause of sepsis after biliary surgery. *Ann Surg* 59 (1977), 328
  85. KEIGHLEY M., LISTER D., JACOBS S. and GILES G.: Hazards of surgical treatment due to microorganisms in the bile. *Surgery* 75 (1974), 578
  86. KEIGHLEY M., DRYSDALE A., QUORAISHI A. BURDON D. and ALEXANDER-WILLIAMS J.: Antibiotics in biliary disease: The relative importance of antibiotic concentration in the bile and serum. *Gut* 17 (1976), 495
  87. KIM W., BARTH K. and ZINNER M.: Seeding of pancreatic carcinoma along the transhepatic catheter tract. *Radiology* 143 (1982), 427
  88. KNUTSEN K. and TEISBERG P.: Alvorlige komplikasjoner til biligrافي (Biligram) ved lymfoproliferative tilstander. *Tidsskr Norsk laegeforen* 6 (1978), 305 (In Nor-
  89. KOYAMA K., TAGAKI Y., ITO K. and SATO T.: Experimental and clinical studies on the effect of biliary drainage in obstructive jaundice. *Amer J Surg* 142 (1981), 293

90. KURODA C., YOSHIOKA H., TOKUNAGA K., HORI S., TANAKA T., NAKAO K., OKAMURA J. and SAKURAI M.: Fine-needle aspiration biopsy via percutaneous transhepatic catheterization: Technique and clinical results. *Gastrointest Radiol* 11 (1986), 81
91. LAMMER J.: Perkutane transhepatische Gallengangsendo-prothese. *Materialwahl, Technik, klinische Ergebnisse. Fortschr Röntgenstr* 142 (1985), 243
92. LAMMER J. and NEUMAYER K.: Transhepatic endoprosthesis for relief of malignant obstructive jaundice. *Ann de Radiol* 29 (1986), 245
93. LEAR J., RING E., MACOVIK J. and BAUM S.: Percutaneous transhepatic electrohydraulic lithotripsy. *Radiology* 150 (1984), 589
94. LEVINSON J.D., OLSEN G., TERMAN J.W., CLEVELAND C.R., GRAHAM Jr C.P. and BREEN K.J.: Hemobilia secondary to percutaneous liver biopsy. *Arch Int Med* 130 (1972), 396
95. LINDSKOG B.I.: Evaluation of operative cholangiography in gall-stone surgery with special reference to residual stones. Thesis, Lund (1970)
96. MACK E., CRUMMY A. and BABAYAN V.: Percutaneous trans-hepatic dissolution of common duct stones. *Surgery* 90 (1981), 584
97. MARIONS O.: Percutan transhepatisk cholangiografi, selektiv visceral angiografi och direkt portografi i ikterusdiagnostik. *Opusc Med Suppl No. 32* (1974), 69 (In Swedish)
98. MARIONS O. and WIECHEL K-L.: Percutan transhepatisk cholangiografi. Indikationer, teknik, komplikationer och diagnoskriterier. *Opusc Med Suppl No. 32* (1974), 1 (In Swedish)
99. MARKS W., FREENY P., BALL T. and GANNAN R.: Endoscopic retrograde biliary drainage. *Radiology* 152 (1984), 357
100. MARTIN E., KARLSON K., FANKUCHEN E., MATTERN R. and CASARELLA W.: Percutaneous transhepatic dilatation of intrahepatic biliary strictures. *Amer J Roentgenol* 135 (1980), 837
101. MATHIESEN D., ATHANASOULIS C. and MALT R.: Preservation of arterial flow to the liver; Goal in treatment of extrahepatic and posttraumatic intrahepatic aneurysms of the hepatic artery. *Ann Surg* 196 (1982), 400
102. McNULTY J.: Drip-infusion cholecystocholangiography. *Radiology* 90 (1968), 570

103. McPHERSON G., BENJAMIN I., HABIB N., BOWLEY N. and BLUMGART L.: Percutaneous transhepatic drainage in obstructive jaundice: Advantages and problems. *Brit J Surg* 69 (1982), 261
104. McPHERSON G., BENJAMIN I., HODGSON H., BOWLEY N., ALLISON D. and BLUMGART L.: Preoperative percutaneous transhepatic biliary drainage: The results of a controlled trial. *Brit J Surg* 71 (1984), 371
105. McSHERRY C.K.: Cholecystectomy and common duct explorations. In: *The biliary tract* (Ed.: BLUMGART L.H.), *Clin Surg Internat* 5 (1982), Churchill Livingstone, Edinburgh
106. MENDEZ G., RUSSELL E., LEVI J., KOOLPE H. and COHEN M.: Percutaneous brush biopsy and internal drainage of biliary tree through endoprosthesis. *Amer J Roentgenol* 134 (1980), 653
107. MENDEZ G., RUSSELL E., LePAGE J., GUERRA J., POSNIAK R. and TREFLER M.: Abandonment of endoprosthetic drainage technique in malignant biliary obstruction. *Amer J Roentgenol* 143 (1984), 617
108. MIRRIZZI P.L.: Operative cholangiography. *Surg Gynecol Obstet* 65 (1937), 705
109. MITCHELL S., SHUMAN L., KAUFMAN S., CHANG R., KADIR S., KINNISON M. and WHITE R.: Biliary catheter drainage complicated by hemobilia: Treatment by balloon embolotherapy. *Radiology* 157 (1985), 645
110. MOLNAR W. and STOCKUM A.: Transhepatic dilatation of choledochenterostomy strictures. *Radiology* 129 (1978), 59
111. MOLT P., HOPFAN S., WATSON R.C., BOTET J.F. and BREENAN M. F.: Intraluminal radiation therapy in the management of malignant biliary obstruction. *Cancer* 57 (1986), 536
112. MONDEN M., OKAMURA J., KOBAYASHI N., SHIBATA N., HIRAKAWA S., FUJIMOTO T., KOSAKI G., KURODA C. and UCHIDA H.: Hemobilia after percutaneous transhepatic biliary drainage. *Arch Surg* 115 (1980), 161
113. MUELLER P., HARBIN W., FERRUCCI Jr J., WITTENBERG J., and van SONNENBERG E.: Fine-needle transhepatic cholangiography: Reflections after 450 cases. *Amer J Roentgenol* 136 (1981), 85
114. MUELLER P., van SONNENBERG E. and FERRUCCI Jr J.: Percutaneous biliary drainage: Technical and catheter-related problems in 200 procedures. *Amer J Roentgenol* 138 (1982), 17

115. MUELLER P., FERRUCCI Jr J., TEPLICK S., van SONNENBERG E., HASKIN P., BUTCH R. and PAPANICOLAOU N.: Biliary stent endoprosthesis: Analysis of complications in 113 patients. *Radiology* 156 (1985), 637
116. MURO A., MUELLER P., FERRUCCI Jr J. and TAFT P.: Bile cytology. A routine addition to percutaneous biliary drainage. *Radiology* 149 (1983), 846
117. NAKAYAMA T., IKEDA A. and OKUDA K.: Percutaneous transhepatic drainage of the biliary tract. *Gastroenterol* 74 (1978), 554
118. NEFF C., MUELLER P., FERRUCCI Jr J., DAWSON S., WITTENBERG J., SIMEONE J., BUTCH R. and PAPANICOLAOU N.: Serious complications following transgression of the pleural space in drainage procedures. *Radiology* 152 (1984), 335
119. NICHOLS D., COOPERBERG P., GOLDING R. and BURHENNE H.J.: The safe intercostal approach? Pleural complications in abdominal interventional radiology. *Amer J Roentgenol* 141 (1984), 1013
120. NORLANDER A., KALIN B. and SUNDBLAD R.: Effect of percutaneous transhepatic drainage upon liver function and postoperative mortality. *Surg Gynecol Obstet* 155 (1982) 161
121. NORMAN O.: Studies on the hepatic ducts in cholangiography. *Acta Radiol Suppl* No. 84 (1951)
122. NUNEZ Jr D., GUERRA Jr J.J., AL-SHEIKH W.A., RUSSELL E. and MENDEZ Jr G.: Percutaneous biliary drainage in acute suppurative cholangitis. *Gastrointest Radiol* 11 (1986), 85
123. OKUDA K.: Thin needle percutaneous transhepatic cholangiography - Historical review. *Endoscopy* 12 (1980), 2
124. OKUDA K., TANIKAWA K., ENURA T., KURATOMI S., JINNOUCHI S., URABE K. et coll.: Nonsurgical, percutaneous transhepatic cholangiography. Diagnostic significance in medical problems of the liver. *Dig Dis* 19 (1974), 21
125. OKUDA K., MUSA H., NAKAJIMA Y., TAKAYASU K., SUZUKI Y., MORITA M. and YAMASAKI T.: Frequency of intrahepatic arteriovenous fistula as a sequela to percutaneous needle puncture of the liver. *Gastroenterology* 74 (1978), 1204
126. OLEAGA J., RING E., FREIMAN D., McLEAN G. and ROSEN R.: Extension of neoplasm along the tract of a transhepatic tube. *Amer J Roentgenol* 135 (1980), 841

127. PASSARIELLO R., PAVONE P., ROSSI P., SIMONETTI G., MODINI C., LASAGNI P., MANNELLA P., GAZZANIGA G., PAOLINI R., IACCARINO V., FELTRIN G., ROVERSI R. and MALLARINI G.: Percutaneous biliary drainage in neoplastic jaundice. Statistical data from a computerized multi-center investigation. *Acta Radiol Diagnosis* 26 (1985), 681
128. PEREZ M., OLEAGA J., FREIMAN D., McLEAN G. and RING E.: Removal of a distal common bile duct stone through percutaneous transhepatic catheterization. *Arch Surg* 114 (1979), 107
129. PERLBERGER R.: Control of hemobilia by angiographic embolization. *Amer J Roentgenol* 128 (1977), 672
130. PITT H., GOMES A., LOIS J., MANN L., DEUTSCH L. and LONGMIRE Jr W.: Does preoperative percutaneous biliary drainage reduce operative risk or increase hospital cost? *Ann Surg* 201 (1985), 545
131. PREGER L.: Hepatic arteriovenous fistula after percutaneous liver biopsy. *Amer J Roentgenol* 101 (1967), 619
132. PREMPREE T., COX E., SEWCHAND W. and TANG C-K.: Cholangiocarcinoma. A place for brachytherapy. *Acta Radiol Oncol* 22 (1983), 353
133. RAINES D., van HEERTUM R. and JOHNSON L.: Intrahepatic hematoma: A complication of percutaneous liver biopsy. *Gastroenterology* 67 (1974), 284
134. REUTER S., REDMAN H. and SIDERS D.: Spectrum of angiographic findings in hepatoma. *Radiology* 94 (1970), 89
135. ROKKJAER M. and KRUSE A.: Endoskopisk galdevejsdrainage ved malign okklusiv icterus. *Ugeskr laeger* 146 (1984), 1126 (Summary in English)
136. ROSATO E., BERKOWITZ H. and ROBERTS B.: Bile ascites. *Surg Gynecol Obstet* (1970), 494
137. ROSEN R. and ROTHBERG M.: Transhepatic embolization of hepatic artery pseudoaneurysm following biliary drainage. *Radiology* 145 (1982), 532
138. RUSSELL E., HUTSON D.G., GUERRA Jr J., NUNEZ Jr D., YRIZARRY J. and SCHIFF E.: Dilatation of biliary strictures through a stomatized jejunal limb. *Acta Radiol Diagnosis* 26 (1985), 283
139. SAFRANY L.: Endoscopic treatment of biliary tract diseases. *Lancet* 2 (1978), 983

140. SALOMONOWITZ E., CASTANEDA-ZUNIGA W., LUND G., CRAGG A., HUNTER D., COLEMAN C. and AMPLATZ K.: Balloon dilatation of benign biliary strictures. *Radiology* 151 (1984), 613
141. SCOTT A.J. and KHAN G.A.: Origin of bacteria in bile duct bile. *Lancet* 2 (1967), 790
142. SEIFERT E.: Endoscopic papillotomy and removal of gall stones. *Amer J Gastroenterol* 69 (1978), 154
143. SELDINGER S.: Percutaneous transhepatic cholangiography. *Acta Radiol Suppl No.* 253 (1966)
144. SEVERINI A., BELLOMI M., COZZI G., BELLEGOTTI L. and LATTUADA A.: Rib erosion: Late complication of long-standing biliary drainage catheters. *Radiology* 150 (1984), 566
145. SHEHADI W. and TONIOLO G.: Adverse reactions to contrast media. *Radiology* 137 (1980), 299
146. SOLIN L. and MOHIUDDIN M.: Subcutaneous seeding of pancreatic carcinoma along a transhepatic biliary catheter tract. *Brit J Radiol* 56 (1983), 883
147. van SONNENBERG E., HOFMANN A., NEOPTOLEMUS J., WITTICH G., PRINCENTHAL R. and WILLSON S.: Gallstone dissolution with methyl-tert-butyl ether via percutaneous cholecystostomy: Success and caveats. *Amer J Roentgenol* 146 (1986), 865
148. STANLEY J., GOBIEN R., CUNNINGHAM J. and ANDRIOLE J.: Biliary decompression: An institutional comparison of percutaneous and endoscopic methods. *Radiology* 158 (1986), 195
149. SUZUKI Y., KOBAYASHI A., OHTO M., TSUCHIYA Y., SAISHO H., KIMURA K., ONO T. and OKUDA K.: Bacteriology of transhepatically aspirated bile. *Dig Dis Sci* 29 (1984), 109
150. TAKADA T., HANYU F., KOBAYASHI S. and UCHIDA Y.: Percutaneous transhepatic cholangial drainage: Direct approach under fluoroscopic control. *J Surg Onc* 8 (1976), 83
151. TANAKA N.: Biliary sepsis. An experimental study in rat with special reference to host defense failure in biliary obstruction. Thesis, Lund (1985)
152. TEPLICK S., WOLFERTH Jr C., HAYES Jr M. and AMROM G.: Balloon dilatation of benign postsurgical biliaryenteric anastomotic strictures. *Gastrointest Radiol* 7 (1982), 307

153. THOMPSON W.M., HALVORSEN R.A., FOSTER W.L., ROBERTS L., GIBBONS R., WILLIFORD M.E., KELVIN F.M. and RICE R.P.: Optimal cholangiographic technique for detecting bile duct stones. Amer J Roentgenol 146 (1986), 537
154. TISCHENDORF P.: Röntgenologische Darstellungsqualität und Verträglichkeit verschiedener intravenöser Cholegraphika. Röntgen-Bl 33 (1980), 581
155. TONIOLO G. and BUIA L.: Risultati de una inschiasta nazionali sugli incidenti mortali da iniezione di mezzi di contrasto organo-iodati. Radiol Med 52 (1966), 625
156. TRINEZ G., LORRIAUX A., RROZAN R., MIZON J.P. and CAPRON J.P.: Etude angiographique d'une fistule hepatico-portale secondaire a une ponction-biopsie du foie. J Radiol Electrol 50 (1969), 817
157. TYLEN U., HOEVELS J. and VANG J.: Percutaneous transhepatic cholangiography with external drainage of obstructive biliary lesions. Surg Gynecol Obstet 144 (1977), 13
158. VOGEL S., HOWARD R., CARIDI J. and HAWKINS I.: Evaluation of percutaneous transhepatic balloon dilatation of benign biliary strictures in high-risk patients. Amer J Surg 149 (1985), 73
159. VOYLES R.: The exoendoprosthesis in proximal bilioenteric anastomoses. Amer J Surg 149 (1985), 80
160. WALLACE S., MEDELLIN H. and NELSON R.: Angiographic changes due to needle biopsy of the liver. Radiology 105 (1972), 13
161. WALSH D.B., ECKHAUSER F.E., CRONENWETT J.L., TURCOTTE J.G. and LINDENAUER S.M.: Adenocarcinoma of the ampulla of Vater. Diagnoses and treatment. Ann Surg 195 (1982), 152
162. WALTER J., PAASO B. and CANNON W.: Successful transcatheter embolic control of massive hemato-bilia secondary to liver biopsy. Amer J Roentgenol 127 (1976), 847
163. WAY L.W. and DUNPHY J.: Biliary stricture. Amer J Surg 124 (1972), 287
164. WHITE T. and HART M.: Cholangiography and small duct injury. Amer J Surg 149 (1985), 640
165. WIECHEL K-L.: Taktiska bedömningar före pancreaticoduodenectomi. Opusc Med 11 (1966), 315 (In Swedish)



166. WIECHEL K-L.: Erfarenheter av 10 års rutinanvändning av PTC. Nord Med 86 (1971), 911 (In Swedish)
167. WIECHEL K-L.: Percutant avlägsnande av gallgångskonkrement. Sv Kir Fören 30 (1973), 200 (In Swedish)
168. WIECHEL K-L. and MARIONS O.: Taktiska synpunkter på gallvägsdiagnostik hos anicteriska patienter. Sv Kir Fören 31 (1974), 88 (In Swedish)
169. WILKINSON S., MOODIE H., STOMATAKIS J. et coll.: Endotoxaemia and renal failure in cirrhosis and obstructive jaundice. Brit Med J 2 (1976), 1415
170. WOLOCHOW H., HILDEBRAND G.J. and LAMANA C.: Translocation of microorganisms across the interstitial wall of the rat. Effect of microbial size and concentration. J Infect Dis 166 (1966), 523