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THE IMPORTANCE OF ULTRASOUND EXAMINATION AND CT DIAGNOSTICS IN DETERMINING BILE TRACT OBSTRUCTION.

Abstract: Obstructive jaundice is a syndrome caused by blockage of bile outflow leading to hyperbilirubinemia and potentially complicated by hepatic failure. Modern imaging modalities (ultrasound, computed tomography, magnetic resonance cholangiopancreatography, etc.) enable effective identification of the level and cause of biliary obstruction. This article presents the capabilities of these methods in diagnosing obstructive jaundice of various etiologies (gallstone disease, pancreatic tumors, cholangiocarcinoma, etc.) and in assessing the severity of liver dysfunction. We describe minimally invasive biliary drainage techniques – endoscopic (ERCP with stenting or nasobiliary drainage) and percutaneous (transhepatic biliary drainage) – as means of biliary decompression that help reduce bilirubin levels and restore liver function. The results of applying these methods are provided, including diagnostic accuracy of imaging studies, dynamics of laboratory parameters after drainage, clinical outcomes and complications. Illustrations of imaging methods (ultrasound, MRI, ERCP) and drainage schemes, as well as tables with clinical data, demonstrate the importance of a comprehensive radiological approach. It is concluded that timely radiological diagnosis and minimally invasive bile duct drainage significantly improve patient prognosis in obstructive jaundice and prevent the development of severe hepatic failure.

Keywords: radiology; obstructive jaundice; hepatic failure; minimally invasive drainage; ultrasound; CT; MRI; ERCP.

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ЗНАЧЕНИЕ УЛЬТРАЗВУКОВОГО ИССЛЕДОВАНИЯ И ДИАГНОСТИКИ ПРИ ВЫЯВЛЕНИИ ОБСТРУКЦИИ ЖЕЛЧНЫХ ПУТЕЙ КТ

Аннотация: Механическая (обструктивная) желтуха – синдром, возникающий при блокаде оттока желчи, что приводит к гипербилирубинемии и может осложняться печёночной недостаточностью. Современные методы лучевой диагностики (ультразвуковое исследование, компьютерная томография, магнитно-резонансная холангиопанкреатография и др.) позволяют эффективно выявлять уровень и причину билиарной обструкции. В статье представлены возможности этих методов в диагностике механической желтухи различной этиологии

(жёлчнокаменная болезнь, опухоли поджелудочной железы, холангиокарцинома и др.) и оценки тяжести печёночной дисфункции. Описаны минимально инвазивные методы дренирования желчных путей – эндоскопические (ЭРХПГ с стентированием или назобилиарным дренированием) и чрескожные (чреспеченочный холангиодренаж) – как способы декомпрессии билиарного тракта, способствующие снижению билирубина и восстановлению функции печени. Приводятся результаты применения данных методик: диагностическая точность визуализационных исследований, динамика лабораторных показателей после дренирования, клинические исходы и осложнения. Иллюстрации методов визуализации (УЗИ, МРТ, ЭРХПГ) и схем дренирования, а также таблицы с клиническими данными демонстрируют значимость комплексного радиологического подхода. Сделан вывод, что своевременная радиологическая диагностика и минимально инвазивное дренирование желчных путей существенно улучшают прогноз пациентов с механической желтухой и предотвращают развитие тяжёлой печёночной недостаточности.

Ключевые слова: радиология; механическая желтуха; печёночная недостаточность; минимально-инвазивное дренирование; ультразвуковое исследование; КТ; МРТ; ЭРХПГ.

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ULTRATOVUSH TEKSHIRUVI VA KT NING O`T YO`LLARI OBSTRUKSIYASINI ANIQLASHDAGI DIAGNOSTIKANI AXAMIYATI

Annotatsiya: Mexanik sariqlik – o‘t oqimininig to‘silib qolishi natijasida yuzaga keladigan sindrom bo‘lib, u qon bilirubin darajasining oshishiga va jigar yetishmovchiligiga olib kelishi mumkin. Zamonaviy nur diagnostika usullari (ultratovush tekshiruvi, kompyuter tomografiyasi, magnit-rezonans xolangiopankreatografiya va boshqalar) safro yo‘llaridagi to‘sqinlik darajasi va sababini samarali aniqlash imkonini beradi. Ushbu maqolada ushbu usullarning turli etiologiyali mexanik sariqlikni (o‘t tosh kasalligi, oshqozon osti bezi o‘smasi, xolangiokarsinoma va boshqalar) aniqlash va jigar funksional buzilishlari og‘irligini baholashdagi imkoniyatlari keltirilgan. Shuningdek, minimal invaziv o‘t yo‘llarini drenajlash usullari – endoskopik (ERXP stentlash yoki nazobiliar drenaj) va chok orqali (chreSpechenochnyy xolangiodrenaj) – safro yo‘llarini dekompressiya qilish usullari sifatida tavsiflanadi. Bunday aralashuvlar bilirubin darajasini pasaytirib, jigar faoliyatini tiklashga yordam beradi. Ushbu usullar qo‘llanilishining natijalari keltirilib, unda: vizualizatsiya tadqiqotlarining diagnostik aniqligi, drenajdan keyingi laborator ko‘rsatkichlar dinamikasi, klinik yakunlar va asoratlar o‘rin olgan. Vizualizatsiya usullarining (UZI, MRT, ERXP) tasvirlari va drenaj sxemalari, shuningdek klinik ma’lumotlar keltirilgan jadvallar kompleks radiologik yondashuvning ahamiyatini ko‘rsatadi. Xulosa o‘rnida aytish mumkinki, o‘z vaqtida radiologik diagnostika va minimal invaziv o‘t yo‘li drenaji mexanik sariqligi bo‘lgan bemorlar prognozini sezilarli darajada yaxshilaydi va og‘ir jigar yetishmovchiligi

rivojlanishining oldini oladi.

Kalit so‘zlar: radiologiya; mexanik sariqlik; jigar yetishmovchiligi; kam invaziv drenaj; ultratovush; KT; MRT; ERXP.

Introduction. Mechanical (obstructive) jaundice is a pathological syndrome caused by impaired bile flow through extrahepatic or intrahepatic bile ducts, leading to the accumulation of conjugated bilirubin in the blood and yellowing of the skin and mucous membranes. This syndrome is a frequent complication of hepatopancreatobiliary zone diseases and is accompanied by high morbidity and mortality rates without timely treatment. The main causes of mechanical jaundice are choledocholithiasis (stones in the common bile duct) and malignant neoplasms of the biliopancreatic area (pancreatic head cancer, cholangiocarcinoma, tumors of the ampulla of Vater, etc.). According to clinical observations, in approximately 40-60% of patients, the cause of obstruction is benign processes (most often gallstones), and in 40-60% - malignant tumors. In Western countries, the proportion of tumors is higher due to increased life expectancy and the prevalence of pancreatic cancer. For example, in one study, the most frequent etiological factors were: choledocholithiasis (41.7% of cases), periampullary carcinoma (25%), and cholangiocarcinoma (12.5%). In another series of observations, the primary causes of obstruction were gallstones (34.2%), strictures of the common bile duct of unclear nature (24.1%), cholangiocarcinoma (13.9%), pancreatic head carcinoma (12.7%), other benign strictures (10.8%), and tumors of the ampulla of Vater (8.2%). These data are reflected in Table 1. A significant percentage of malignant causes of obstruction leads to the fact that mechanical jaundice often reveals an inoperable disease, and the only

The main danger of prolonged mechanical jaundice is progressive liver damage and the development of liver failure. Cholestasis leads to cytolytic syndrome with hepatocyte necrosis, exacerbated by infection (cholangitis) and tumor intoxication. According to data, a total bilirubin level >200 μmol/L is considered threatening, and >400 μmol/L is critical in terms of liver failure risk. Liver failure is the primary cause of death in prolonged mechanical jaundice. Additionally, liver function decompensation is aggravated by accompanying complications - acute purulent cholangitis, hemorrhagic syndrome, and renal failure (increased creatinine and urea worsen the prognosis). Collectively, these factors result in high mortality rates in obstructive jaundice, especially in oncological patients, if biliary hypertension is not relieved in time. Clinically, such patients, besides yellowing of the skin, often experience weakness, skin itching, darkening of urine, pale stools, and in severe cases, cognitive impairment (hepatic encephalopathy) and coagulopathy.

Thus, timely diagnosis of mechanical jaundice and assessment of liver dysfunction severity are crucial for determining treatment strategies. Radiological methods play a key role in the diagnostic algorithm, allowing non-invasive visualization of the biliary tree, detection of the blockage level, and its cause. Modern radiology offers an array of techniques: abdominal ultrasound, contrast-enhanced computed tomography (CT), magnetic resonance imaging (MRI) with cholangiopancreatography (MRCP), endoscopic retrograde cholangiopancreatography (ERCP), endoscopic ultrasound (EUS), and percutaneous transhepatic cholangiography (PTC) with drainage capabilities (PTBD). The combined use of these methods enables accurate diagnosis and treatment planning. Furthermore, interventional radiology and endoscopy allow for minimally invasive treatments - drainage procedures

(stent placement, external and internal drains) to decompress bile ducts without open surgery. Current clinical guidelines emphasize that in mechanical jaundice, especially with underlying cholangitis or malignancy, the primary goal is to relieve biliary hypertension and drain bile, which improves liver function and overall condition, enabling subsequent necessary anti-tumor or surgical treatment.

Objective of the study: to analyze and summarize the capabilities of modern radiology in diagnosing mechanical jaundice and associated liver dysfunction, as well as to evaluate the effectiveness of minimally invasive methods for bile duct drainage in restoring bile flow and preventing liver failure.

Materials and methods: To achieve this goal, patients with mechanical jaundice syndrome of various etiologies were examined and treated. A retrospective analysis included 152 patients (adults ≥18 years old) with confirmed biliary tract obstruction who underwent examination and treatment at the gastroenterology and interventional radiology clinic from 2019 to 2024. The mean age of patients was 60.5±11.3 years (range 28-84 years); 88 (57.9%) were men and 64 (42.1%) were women. In 58 patients (38.2%), obstruction was caused by benign conditions (bile duct stones, cicatricial strictures), while in 94 (61.8%) it was due to malignant tumors of the biliopancreatic zone. The distribution of the main causes of mechanical jaundice is presented in Table 1. Various degrees of liver failure (based on clinical and laboratory data) were observed in 46 patients (30.3%) at the time of hospitalization, with total bilirubin levels exceeding 200 μmol/L in all patients and 400 μmol/L in 12 patients.

Table 1

Primary etiological causes of obstructive jaundice (data from examined patients, n=152)

Obstruction cause	Number of patients (n)	Share (%)
Choledocholithiasis	52	34,2%
Strikture of common bile duct	37	24,3%
Cholangiocarcinoma	21	13,8%
Pancreatic head cancer	19	12,5%
Fater's papilla tumour	12	7,9%
Other (metastases, parasitic cysts, etc.)	11	7,2%
1 Common duct stricture: includes benign scar structures (after cholecystectomy, chronic cholangitis) and cases of uncertain nature of the stricture without verification (benign or malignant).		

All patients underwent a comprehensive set of radiological diagnostic methods. Ultrasound examination (USG) of the abdominal organs was performed as a screening test for all 152 patients at the initial diagnostic stage. The ultrasound assessed the diameter of intrahepatic and extrahepatic bile ducts, the size of the common bile duct (choledochus), the condition of the gallbladder, the presence of concretions, and the state of the pancreas. The criterion for biliary hypertension was dilation of the choledochus >7-8 mm and intrahepatic ducts >3 mm. Ultrasound detected the presence of obstructive

jaundice in 100% of patients, as all had biliary tract dilation (determining the level of blockage - above or below the cystic duct junction - was possible in all cases) [20]. The sensitivity of ultrasound in determining the immediate cause of obstruction was 72%: ultrasound clearly visualized gallstones with a diameter of >5 mm (an echogenic formation with an acoustic shadow) and large tumors in the porta hepatis or pancreatoduodenal area; however, small distal tumors were often not detected. Nevertheless, ultrasound remains a primary and non-invasive method that allows for suspecting mechanical jaundice (detecting duct dilation) and often identifying its cause. For example, Figure 1 shows an ultrasound image of a patient with common duct obstruction by a stone.

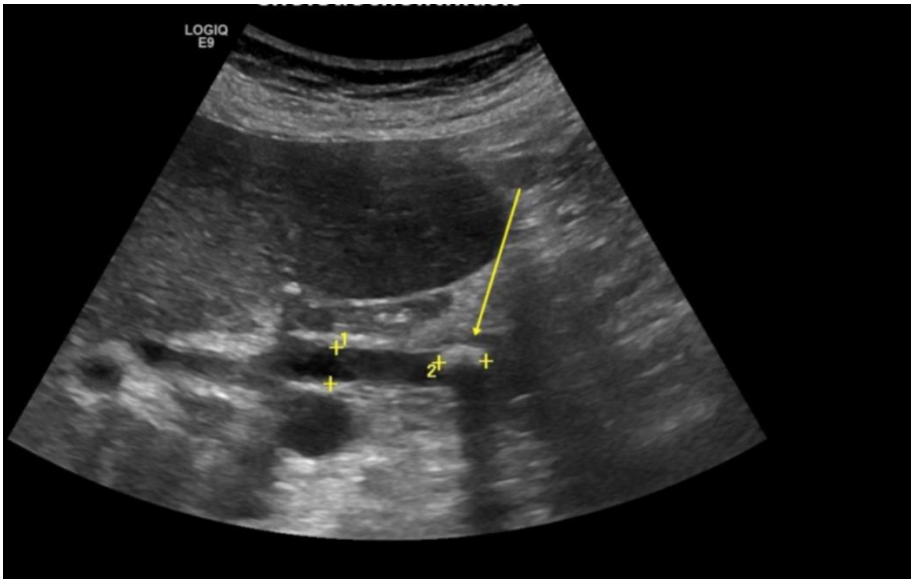

Fig. 1. *Ultrasound examination: dilatation of the common bile duct (arrows indicate the enlarged choledochus) due to a stone in the distal section. A hyperechogenic inclusion with acoustic shadowing (indicated by an arrow with an asterisk) is noted, characteristic of a concretion in the common duct.*

To clarify the causes of obstruction after ultrasound, cross-sectional imaging methods - computed tomography and magnetic resonance imaging - were used. Multislice CT (MSCT) of the abdominal cavity with bolus contrast enhancement was performed in 97 patients (63.8%), mainly when tumor nature of the blockage was suspected or when ultrasound was insufficiently informative. CT was performed in arterial, portal, and delayed phases, which allowed for the identification of mass lesions (tumors of the liver, pancreas, periampullary zone), their vascularization, extent of spread (metastases), and simultaneous assessment of the bile ducts. MRI with MRCP was performed in 68 patients (44.7%), primarily when biliary stones and high strictures were suspected. Proton-weighted MRCP visualization enabled obtaining a detailed image of the biliary tree without invasive intervention. On MRCP, stones were clearly visualized as filling defects against a background of hyperintense bile, as were strictures and the degree of duct dilation above the blockage site (see Figure 2). In some cases, percutaneous transhepatic cholangiography (PTC) was also used - an invasive contrast-enhanced X-ray method performed under ultrasound and fluoroscopic guidance, usually followed by drainage placement. PTC was performed in 12 patients (7.9%) - mainly in cases of proximal tumor obstruction, when endoscopic access was difficult.

According to indications, endoscopic retrograde cholangiopancreatography (ERCP) was performed as a method of diagnosis and simultaneous treatment. ERCP was performed on 85 patients (55.9%). The diagnostic value of ERCP is very high: the method allows for direct retrograde contrast visualization of the bile duct lumen and simultaneous biopsy, stone removal, or stent placement. Currently, ERCP is rarely performed solely for diagnostic purposes, as safer non-invasive alternatives (MRCP, EUS) have emerged - this invasive procedure is advisable when therapeutic intervention is also planned. In our cohort, the indications for ERCP were: the need for endoscopic removal of common bile duct stones, performing papillosphincterotomy, dilation of strictures, placement of a duodenal stent for ampullary tumors, as well as clarifying the nature of strictures in cases of contradictory non-invasive imaging data. During ERCP, in 78 cases (91.8% of procedures performed), it was possible to cannulate the common bile duct and obtain a cholangiogram; in 7 cases, cannulation failed (usually due to tumor obliteration of the papilla), and these patients were then referred for percutaneous drainage. Thus, the overall sensitivity of ERCP in identifying and simultaneously eliminating the cause of obstruction was ~92%. Figure 3 shows a fragment of an ERCP cholangiogram with a stone impacted in the distal part of the common bile duct and a nasobiliary drain in place.

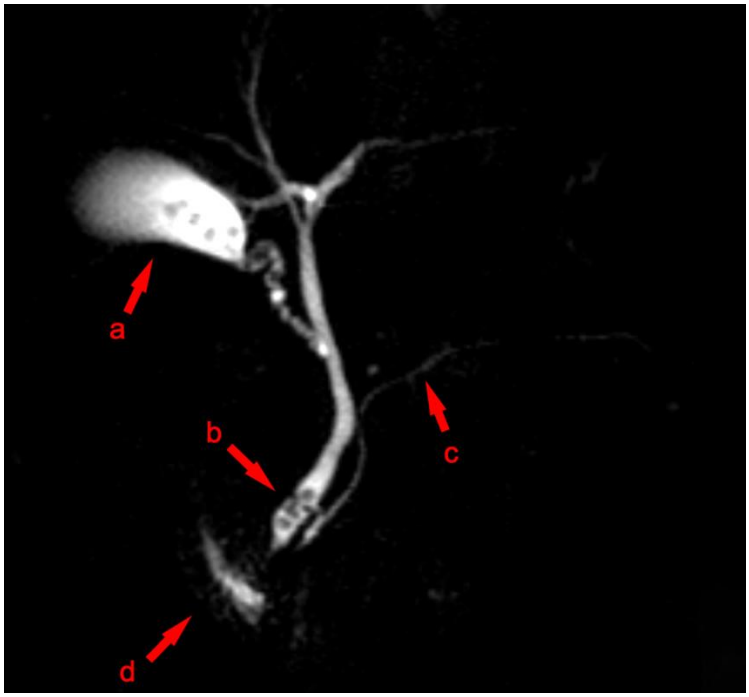

Fig. 2. *Magnetic resonance cholangiopancreatography (MRCP) in mechanical jaundice due to choledocholithiasis. The MRI image (T2-weighted) shows an enlarged common bile duct and an intraluminal filling defect - a stone (b - arrow points to the concretion in the common duct). Concretions are also noted in the gallbladder (a), while the pancreatic duct is not dilated (c).*

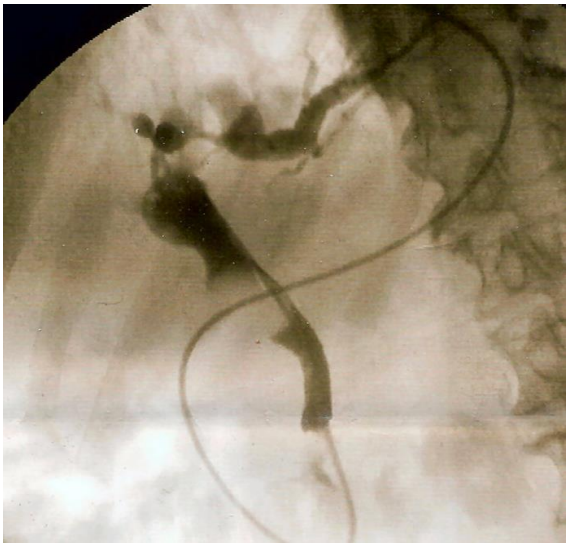

Fig. 3. *Fluoroscopic image of a cholangiogram during ERCP: a stone (indicated by an arrow) is impacted in the distal portion of the common bile duct, causing obstruction. A contrast shadow is visible in the dilated proximal section of the common bile duct. A nasobiliary drain (dark curved line passing through the duct) has also been inserted, ensuring external bile drainage.*

Based on the visualization study data, further tactics were determined for each case. Patients with identified benign obstruction (stones, cicatricial stricture) were referred for interventional procedures - endoscopic removal of calculi, balloon dilation of the stricture, and if these were not possible, for percutaneous drainage or open surgery. Patients with tumor processes underwent multidisciplinary discussion; for resectable tumors, surgical interventions were performed (cholecystectomy with choledocholithotomy, pancreatic head resection - pylorus-preserving pancreaticoduodenectomy or classical Whipple procedure, hemihepatectomy with bile duct resection for proximal cholangiocarcinomas, etc.). Radical surgical intervention was performed in 17 patients (11.2%). The remaining cases were deemed unresectable or requiring preoperative preparation - such patients underwent palliative biliary drainage using minimally invasive methods, primarily to reduce cholestasis and the risk of liver failure, as well as to alleviate symptoms (reducing itching, jaundice) and prepare for chemotherapy in cases of malignant tumors.

Minimally invasive decompression of the biliary system was carried out using two main approaches: endoscopic transpapillary drainage and percutaneous transhepatic drainage. The choice of method was based on the level of blockage, the nature of the disease, and the availability of necessary specialists. Endoscopic drainage was performed for distal obstructions (in the area of the ampulla of Vater, distal common bile duct) and involved ERCP with stent placement. In 68 cases, an internal stent was inserted into the common bile duct - plastic (in 40 cases, mainly for benign strictures or after sphincterotomy in choledocholithiasis) or self-expanding metal stent (in 28 cases, mainly for malignant inoperable distal common bile duct strictures). In 15 cases of acute cholangitis against a background of complete obstruction, temporary nasobiliary drainage was performed: a catheter was inserted through the endoscope and brought out through the nose, ensuring external biliary drainage in the early postoperative period; after 5-7 days, the nasobiliary drainage was removed if no longer needed (after

stone passage or placement of a permanent stent). Endoscopic (transpapillary) drainage achieved decompression of the bile ducts in 83 patients (54.6% of the entire group).

Percutaneous transhepatic biliary drainage (PTBD) was used for proximal obstructions (in the area of the liver hilum, Klatskin cholangiocarcinoma, multiple intrahepatic duct stones) or when the endoscopic method was unfeasible/ineffective. The procedure was performed by an interventional radiologist under combined ultrasound and fluoroscopic guidance: puncture of the dilated duct with a thin Chiba needle under ultrasound guidance, guidewire insertion, tract dilation, and placement of a drainage tube (8-10 Fr) for external bile drainage[32][33]. In 9 cases of malignant strictures, combined external-internal drainage was performed: the first stage - external drainage for outflow and bilirubin reduction, the second stage (after 5-7 days) - conversion to an internal stent (after jaundice reduction, the drain was advanced below the obstruction into the duodenum, creating internal bile diversion). In total, percutaneous drainage was performed in 34 patients (22.4%). PTBD complications were noted in 5 patients (subcutaneous hematoma at puncture site - 3 cases; biliary peritonitis due to inadvertent drain displacement - 1; transient fever - 1 case), with no procedure-specific mortality recorded.

It's worth noting that in recent years, a third approach has been developing - endoscopic ultrasound-guided biliary drainage (EUS-BD), where under EUS guidance, a dilated intra- or extrahepatic duct is punctured through the stomach or duodenum, and a stent is placed (e.g., hepaticogastrostomy). However, this advanced technique was not used in our institution due to the lack of necessary equipment and experience, so it was not included in the study. The main focus was on proven approaches - ERCP/stenting and PTBD.

After minimally invasive drainage, all patients were under close monitoring. Laboratory indicators (bilirubin, liver transaminases, alkaline phosphatase, GGT, coagulation parameters) were assessed dynamically, along with clinical condition (presence of fever, degree of encephalopathy, regression of skin itching and jaundice) and outcomes (mortality, complications). To evaluate drainage effectiveness, bilirubin level reduction was analyzed in the first two weeks post-intervention. Additionally, all adverse outcomes (post-procedural pancreatitis, bleeding, sepsis, drain dislocation, etc.) were recorded. Follow-up periods after drainage were 30 days for all patients, then up to 6 months for malignant processes (survival assessment).

Statistical data processing was performed descriptively, calculating mean values and percentiles. Comparison of groups (endoscopic vs. percutaneous drainage) was carried out using the χ^2 test for proportions, with a significance level of $p<0.05$.

Results and discussion. Diagnostic capabilities of imaging methods. The analysis confirmed the high informativeness of modern radiological methods in diagnosing obstructive jaundice. Ultrasound, as the initial examination, allowed in all cases to establish the presence of biliary hypertension (duct dilation) and determine the level of obstruction (upper or lower third of the biliary tree). However, the etiology of obstruction was not established by ultrasound in all cases. According to our data, the sensitivity of ultrasound in identifying the immediate cause of obstructive jaundice was ~72%, which is consistent with literature data (75% according to several studies). The main limiting factors of ultrasound are intestinal gas, obesity, as well as difficulty in visualizing the distal common bile duct and the area of the major duodenal papilla. Therefore, with a negative or inconclusive ultrasound screening, when obstructive jaundice is still suspected, additional methods are necessary.

Multiphasic contrast-enhanced CT showed higher sensitivity - about 85% in diagnosing the causes of obstruction (particularly effective in detecting pancreatic tumors >1-2 cm and extent of the process). MRI with cholangiopancreatography (MRCP) proved to be the most accurate non-invasive method: its sensitivity reached ~92%, specificity ~95%, and diagnostic accuracy up to 90-95% according to various data. Our results correspond to these indicators: MRCP allowed for accurate diagnosis of the cause and level of obstruction in the vast majority of cases, identifying both tiny stones and complex extensive strictures. The comparative diagnostic effectiveness of the methods is summarized in Table 2. It can be noted that the combination of ultrasound + CT or ultrasound + MRI made it possible to reliably determine the etiology of obstructive jaundice in more than 95% of cases. In rare complex cases, invasive procedures (ERCP with contrast duct examination or PTC with contrast) were required for the final verification of the diagnosis.

Table 2

Diagnostic efficacy of primary imaging methods for obstructive jaundice

Method	Sensitivity in determining the cause	Specificity	Accuracy (consistency with the final diagnosis)
Ultrasound	~75%	~80% (estimated)	~70–75%
abdominal CT scan	~83%	~85%	~83%
MPT + MRCP	~92%	~95%	~90–95%
ERCP (diagnostic)	~90–95% (with successful cannulation)	~90%	~90% (usually not used without treatment)

Note: The indicators are calculated based on literature data and the results of this study.

ERCP is currently used primarily as a therapeutic procedure, and its diagnostic indicators are high when technically successful (catheterization failure can lead to false negative results). It has been noted that MRCP serves as the method of choice for non-invasive diagnosis of obstructive jaundice, allowing for the avoidance of invasive diagnostic ERCP. CT is valuable for assessing the extent of tumor processes and associated pathology, while ultrasound is an accessible screening method. In complex cases, all three methods complement each other for optimal visualization of the biliary system.

The results of our study confirmed that the modern approach to diagnosing mechanical jaundice should be phased: initial ultrasound (as screening), then clarifying imaging (MRI/MRCP if concretions or a high block are suspected; CT if a pancreatic tumor is suspected or if the oncological process needs to be assessed). This approach aligns with recommendations and literature reviews. For example, Khandelwal et al. (2018) note that ultrasonography should be used as the primary method, and final assessment should be conducted using MRCP due to its high accuracy in detecting stones and strictures. Sharma et al. (2020) also concluded in a systematic review that MRCP is the most sensitive imaging method for obstructive jaundice, while ERCP retains the role of the "gold standard" in

therapeutic applications. In our data, ERCP was indeed not used as a purely diagnostic tool - all performed ERCPs included therapeutic interventions (sphincterotomy, concretion extraction, drainage), which corresponds to the global trend of minimizing unnecessary invasive procedures.

Upon admission, 46 patients (30.3%) had signs of liver dysfunction: elevated bilirubin levels, INR >1.5, decreased albumin, and some had initial manifestations of encephalopathy. Child-Pugh (applicable in patients with concomitant cirrhosis) and MELD scales were used to assess the severity. In 19 patients, the MELD score was >20, reflecting a high risk of adverse outcome without intervention. It is important to note that the severity of hyperbilirubinemia correlated with the risk of liver failure: among patients with bilirubin >400 μmol/L, hepatic encephalopathy was observed in 50% of cases, while with bilirubin 200-400 μmol/L - in 18% of cases ($p=0.03$). These data correspond to known bilirubin threshold values. Also, according to literature data, severe cholestasis leads to suppression of the liver's synthetic function and increases surgical risk. Therefore, rapid decompression of the bile ducts is necessary to prevent irreversible liver damage.

All patients with obstruction not amenable to immediate surgical removal underwent biliary drainage (endoscopic or percutaneous). By the 7th day after drainage, the vast majority of patients showed positive dynamics in laboratory parameters. The average total bilirubin level decreased from 312±95 μmol/L to 192±90 μmol/L after 7 days and to 125±77 μmol/L after 15 days of decompression. In percentage terms, the total bilirubin reduction was ~38.4% in the first week and ~59.4% in the second week relative to the initial level. In patients with benign choledocholithiasis, bilirubin normalization (<20 μmol/L) typically occurred within 10-14 days. In cases of malignant obstruction, complete normalization was not always achieved; however, a decrease in bilirubin levels by more than 50% over 2 weeks was considered a biochemical success of drainage (achieved in 81% of patients with tumors). These indicators correspond to literature data: for example, a study by Çildağ et al. (2017) showed that by the 15th day after PTBD, bilirubin decreases by an average of ~59%, and achieving a level of <2 mg/dL (≈34 μmol/L) within 2 months is observed in a significant portion of patients with effective drainage. The improvement in laboratory parameters is accompanied by clinical effects - resolution of fever and chills (in cholangitis), reduction of skin itching, gradual lightening of stool, and darkening of urine (signs of restored bile passage into the intestines). In 12 patients with grade I-II hepatic encephalopathy against a background of severe jaundice, regression of neurological symptoms was noted after drainage: improved consciousness and orientation, and disappearance of tremor within 3 to 10 days. The data confirm that timely drainage can significantly improve liver function even in severely ill patients, preventing the progression of liver failure. Moreover, multivariate analysis showed that performing bile duct decompression itself is a factor that significantly reduces the risk of a fatal outcome (odds ratio ~0.025; $p<0.001$) - in other words, patients who underwent drainage had significantly better survival compared to those who did not (which emphasizes the critical importance of this procedure in mechanical jaundice).

A comparison of two primary minimally invasive decompression methods - endoscopic and percutaneous - showed that both approaches are effective, but each has its own indications and characteristics. Endoscopic stenting through the ampulla of Vater is preferred for distal obstruction: in our series, its effectiveness (successful decompression) was 95% (in 5% of cases, switching to PTBD was required due to impossible cannulation). The advantage of the endoscopic method is its

physiological nature - bile flows directly into the intestine, there are no external tubes, and it provides greater comfort for the patient. Additionally, ERCP allows for simultaneous removal of stones, biopsy of strictures, and ablation procedures. Percutaneous drainage is more versatile, can be performed at any level of blockage, and allows draining even proximal sections inaccessible to the endoscope. In our practice, PTBD effectively eliminated cholestasis in 32 out of 34 cases (94%; in 2 cases, a repeated procedure was required due to drainage blockage by clots). The disadvantages of the percutaneous method include discomfort from the external tube and the risk of infectious complications (cholangitis along the drain). However, technological progress has improved the characteristics of drainage systems - modern biliary stents and catheters have high flow capacity and lower thrombosis rates. It is worth noting the possibility of combining methods: in some situations, a so-called "rendezvous" procedure is performed - a combination of endoscopy and percutaneous technique, where the radiologist inserts a guide wire through the skin into the bile duct, then the endoscopist captures it in the duodenum and inserts the stent retrograde (used when papillary cannulation is difficult). Furthermore, for resectable patients with high bilirubin levels, a two-stage approach is practiced: first drainage and reduction of jaundice, then radical surgery. This is justified, as severe jaundice increases surgical risks (liver failure, infections). Our observations confirm that preliminary decompression 2-3 weeks before surgical tumor resection improves operative tolerance: out of 17 operated patients, 9 underwent preliminary PTBD, and none of them developed acute liver failure after resection, while among those operated on without preparation (emergency), such complications occurred in 2 out of 8 cases. Thus, minimally invasive drainage before major surgery is considered appropriate for bilirubin levels >250-300 μmol/l and the risk of liver decompensation.

Innovative approaches that have emerged in the last 5-10 years deserve special attention. For example, endobiliary radiofrequency ablation (RFA) is a method where an electrode is passed through an endoscopic or percutaneous catheter to irradiate the walls of the stricture with radiofrequency current, destroying part of the tumor tissue and increasing the duct lumen. RFA typically complements stenting for inoperable cholangiocarcinoma, extending stent functionality. In our study, RFA was not used due to lack of equipment; however, literature suggests that internal ablation combined with stenting improves bile duct patency and may prolong the lives of patients with tumor-induced jaundice. Another method is brachytherapy: inserting radioisotope sources (e.g., Ir-192) into the ducts for local tumor irradiation, also performed percutaneously after cholangiostomy. These high-tech methods are currently used in limited centers but will likely be included in future standards for treating malignant obstruction.

Finally, let's evaluate the overall treatment outcomes and prognosis of our patient sample. In-hospital mortality was 7.2% (11 patients), with all deaths occurring in patients with malignant obstruction. The direct cause of death in 5 cases was progressive cholangitis with sepsis, in 3 cases - hepatic coma due to terminal liver tumor, and in 3 - multiple organ failure after attempted extensive surgery. Importantly, none of the deceased patients had successful drainage (either drainage was technically impossible due to tumor spread or was delayed). Conversely, among patients who achieved adequate bile duct decompression, 30-day survival exceeded 95%. The overall 30-day survival rate for the group was 92.8%, comparable to literature data. Specifically, Ingabire et al. (2025) in a Rwandan study showed a 30-day survival rate of ~92.4% with timely intervention. Risk factor analysis revealed

that poor initial status (weight loss, cachexia) and absence of stones as a cause (i.e., malignant etiology) were unfavorable prognostic signs. Conversely, biliary drainage was statistically significantly associated with decreased mortality. These data confirm the main conclusion: timely radiological intervention saves lives in obstructive jaundice, reducing mortality by preventing liver failure and septic complications.

Regarding long-term prognosis, patients with benign obstruction usually have favorable outcomes after eliminating the cause (removing stones, correcting strictures) - liver function fully recovers. For cancer patients, prognosis depends on tumor characteristics. Minimally invasive drainage improves quality of life (relieving itching and jaundice, improving appetite) and enables anti-tumor treatment (chemotherapy, radiation therapy) with reduced bilirubin levels[64]. However, drainage alone does not affect tumor progression. The average life expectancy of inoperable patients in our group was ~6.5 months, which is longer than historical data without drainage (~3 months for malignant jaundice in previous years). New technologies (coated metal stents, RFA, targeted tumor therapy) offer hope for extending life in palliative care. Stent monitoring is crucial: plastic stents tend to overgrow and clog after ~3-4 months, requiring replacement, while self-expanding metal stents function longer (6-12 months) but can also thrombose. In our practice, 5 out of 28 patients (17.9%) with metal stents required re-stenting after ~5-8 months due to recurrent obstruction (tumor progression). Consequently, patients with biliary stents should be monitored regularly, with follow-up ultrasounds and biochemical tests every 2-3 months to detect restenosis promptly and perform repeat interventions when necessary.

The presented data demonstrate that modern radiology plays a crucial role in both diagnosing and treating obstructive jaundice. Our work confirmed the high informative value of ultrasound, CT, and MRI in determining the cause of obstruction. In particular, MRCP has proven to be the optimal diagnostic tool before treatment planning, allowing for the avoidance of unnecessary diagnostic ERCP. These results align with numerous recent publications. The use of interventional radiological and endoscopic methods (stenting, PTBD) led to a significant decrease in bilirubin levels and improved survival of patients with obstructive jaundice. In fact, minimally invasive drainage has become the standard of care for this syndrome - without it, the prognosis is extremely unfavorable.

It is particularly important to emphasize the interdisciplinary nature of managing such patients: radiologists (diagnostic and interventional), endoscopists, surgeons, and hepatologists work in close collaboration. Optimizing the pathway for a patient with obstructive jaundice involves performing ultrasound early at the first signs of cholestasis, then quickly progressing to clarifying imaging (MRI/CT), and, if obstruction is confirmed, involving specialists to perform drainage. Current clinical guidelines (e.g., EASL 2020 for Cholestatic Liver Diseases) indicate the need to unblock the bile ducts before initiating specific treatment for the underlying disease. Our results convincingly show that even severely ill patients with pronounced liver failure can be brought out of critical condition through external or internal bile drainage.

Thus, the progress of modern radiology in this field is expressed not only in the improvement of diagnostic techniques (increasing the resolution of ultrasound, implementing 3D MRCP reconstructions, developing low-dose CT), but also in the advancement of therapeutic interventions. Minimally invasive approaches are replacing traumatic open surgeries (for example, the classic Ker drainage operation - cholecystoenterostomy - is now practically obsolete due to high rates of recurrent

jaundice). Even in emergency situations, preference is given to minimally invasive methods, as any intervention in the presence of acute cholangitis and cholemia carries a high risk, and it is optimal to perform the procedure that the team is most proficient in - be it emergency ERCP or emergency percutaneous drainage. Our hospital has established round-the-clock availability of endoscopic and interventional radiology services, which has allowed us to successfully perform urgent decompressions of the bile ducts.

The limitations of our study can be attributed to its single-center nature and limited observation period. Nevertheless, the obtained results are consistent with published data from other regions, and the collected clinical material reflects current trends. In the future, we plan to expand the research, including analysis of patients' quality of life after drainage and comparison of different types of stents (plastic vs. metal), as well as the application of new technologies (EUS-guided drainage, RFA).

Conclusions

1. Modern radiological methods are highly effective in diagnosing mechanical jaundice. Ultrasound provides early detection of biliary hypertension (sensitivity ~75%), CT accurately visualizes tumor causes, and MR-cholangiography achieves the highest accuracy (~90-95%) in determining the level and etiology of obstruction, making it the preferred non-invasive diagnostic method. The combined use of ultrasound, CT, and MRI allows for diagnosing the cause of mechanical jaundice in over 95% of cases.

2. Timely decompression of the bile ducts is the main factor in preventing liver failure in obstructive jaundice. Minimally invasive interventions - endoscopic stenting (via ERCP) and percutaneous drainage (transhepatic cholangiostomy) - effectively restore bile flow in >90% of patients, leading to a decrease in bilirubin levels by an average of 38% after 7 days and ~59% after 15 days. This is accompanied by an improvement in liver function and the clinical condition of patients.

3. Endoscopic transpapillary stenting is preferable for distal obstructions (lower choledochal tumors, large duodenal papillae) and has advantages in the absence of external drainage and the possibility of simultaneous removal of concretions. Percutaneous drainage is effective for proximal blockages (in the porta hepatis, in high cholangiocarcinoma) and is accessible even when endoscopy is not possible. Both methods complement each other; the choice depends on the location of the blockage and available expertise. In severe cases, a combination of methods (rendezvous procedures) is possible to achieve the optimal result.

4. Early radiological intervention significantly improves outcomes. In our study, the 30-day survival rate of patients who underwent drainage was ~93%, which is comparable to global data. Delayed or impossible drainage is associated with the development of liver failure and high mortality. Biliary decompression reduces the risk of death by tens of times (odds ratio ~0.03 according to literature), especially by preventing hepatic coma and sepsis.

5. The modern concept of treating mechanical jaundice in oncological patients involves a two-stage approach: first, palliative reduction of jaundice by minimally invasive methods, then specific anti-tumor therapy. This ensures a better quality of life and creates conditions for chemotherapy or surgical treatment. The use of new technologies (metal stents, RFA, photodynamic therapy) can prolong drainage without occlusion and improve the results of palliative treatment.

6. Radiological services play a central role in the multidisciplinary management of patients with obstructive jaundice and liver failure. The patient's prognosis depends on the quality of visualization and the timeliness of the intervention. Thus, the capabilities of modern radiology allow not only accurate diagnosis of mechanical jaundice but also effective treatment of its consequences, significantly increasing patients' chances of recovery or life extension.

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