NORMAL ECHOSEMIOTICS OF RESECTED PARENCHYMATOUS ORGANS

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The aim of the investigation was to develop ultrasonic techniques of the resected liver, pancreas, and kidney, and study their normal echosemiotics after different types of resection.

Materials and Methods. We examined 404 patients after various hepatectomies, 145 — after extended pancreaticoduodenal resections, and 123 — after different types of nephrectomy. Ultrasound was performed on scanners Voluson 730 PRO (GE, USA) and Technos (Esaote, Italy) in early postoperative period — on day 2–3 and on day 7–10, and in follow-up care — 3, 6 and 12 months after the operation.

Results. We developed an ultrasound technique and established sonographic criteria to assess resected parenchymatous organs, represented normal ultrasound semiotics of the liver, pancreas and kidney after different types of resection. The number and location of hepatic veins in hepatic stump was found to be of primary importance in determining the hepatectomy type; and it was called the hepatic vein rule. An additional criterion was the portal vein branching character. The assessment criteria of pancreatic stump were its size in the body of pancreas and diameter of the major pancreatic duct, as well as spatial location of anastomosed loop of jejunum and gastric remnant. During the first postoperative month slight dilatation of Wirsung duct up to 3–4 mm with its following recovery is permissible. In late postoperative period, the duct dilatation over 3 mm is considered pathological. To determine the nephrectomy type it is necessary to assess the form of the organ and the resection area. Normal echogram can be misinterpreted after frontal nephrectomy due to different parenchymal thickness in its resected and remaining parts.

Conclusion. The developed echosemiotics of resected parenchymatous organ in the majority of cases enables to take a correct view of the volume and character of the surgery, and determine postoperative state of the stump.

Key words: diagnostic ultrasound; echosemiotics of resected parenchymatous organs; hepatectomy; pancreaticoduodenal resection; nephrectomy; hepatic veins; portal vein; renal scar.

The main task of ultrasound (US) investigation is the detection of lesions, and their differential diagnosis made preoperatively [1, 2]. Normal abdominal echosemiotics has been studied comprehensively and in detail, though there are no Russian and foreign reports with a detailed description of ultrasonic image of the resected liver, pancreas or kidney with specific postoperative changes after different types of resections. US is used postoperatively only to reveal complications, most frequently — hematomas and suppurative foci.

To follow up the operated patients an ultrasonographer should know the examination procedure of resected parenchymatous organs, their assessment criteria, and the echopicture features after basic types of operations to avoid misinterpretation of normal images of this postoperative state. The problem is getting more urgent due to a growing number of patients with previous resections of parenchymatous organs, good survival after such operations, in case the patients are followed up by different physicians in different healthcare facilities [3, 4]. The standartization of both diagnostic process itself and normal postoperative semiotics is required to reduce a subjective factor and improve the reproducibility of US findings.

The aim of the investigation was to develop ultrasonic techniques of the resected liver, pancreas, and kidney, and study their normal echosemiotics after different types of resection.

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Materials and Methods. We studied normal semiotics of resected liver, pancreas, and kidney in the Diagnostic Ultrasound Department of Privolgzhsky District Medical Center of Federal Medico-Biologic Agency of Russia (Nizhny Novgorod, Russia) using scanners Voluson 730 PRO (GE, USA) and Technos (Esaote, Italy). In early postoperative period a resected organ was examined twice — on day 2–3 and on day 7–10. Later on the patients were followed up 3, 6 and 12 months after the operation.

During the period from 2005 to 2011 in Privolgzhsky District Medical Center of Federal Medico-Biologic Agency of Russia we performed 404 hepatectomies (including 54 segment- or sectorectomies, 186 — hemihepatectomies (HHE), 164 — extended hemihepatectomies (EHHE), 145 — extended pancreatoduodenectomies, and 123 — nephrectomies (including 58 planar resections, 37 wedge resections, and 28 frontal resections). The etiology of postoperative lesions was of no importance for the resected organ echopicture assessment, for this reason the operated patients in groups were divided into subgroups depending on resection type only.

The US investigation included the grey-scale scanning of the stump with stump location and size determination, and the visual assessment of the residual parenchyma and vascular system in color flow or energy mapping. The resection zone appraisal was an essential stage of the study, and we assessed it by the following aspects: location, dimensions, size, contour, the deformation degree of the organ surface in the resection zone, echogenicity and echostructure of a postoperative scar, the condition of the surrounding organs and tissues, compensatory hypertrophic changes.

The resected liver was first scanned in longitudinal planes, a patient being in supine position, starting from the median line of the body, bending a sensor toward the left shoulder, and moving it along the right costal arch, up to the anterior or midaxillary line. Then in the left lateral position we located the liver subcostally, the scan plane being along the right costal arch at different angles to anterior abdominal wall, moving successively from anterior axillary line towards the median line of the body.

We studied thoroughly the hepatic vascular system examining the portal vein, mounting a sensor perpendicularly the costal arch along the right midclavicular line and directing the scanning axis to the right shoulder. The portal vein bifurcation, its lobar and segmental branches were visualized from a subcostal position, the scan plane being parallel to the costal arch, at cranial angle of 45–60° to the anterior abdominal wall. When examining the lobar branches, the scan axis was directed to the right or to the left inspecting the segmental branches and tracing them deep into the segments.

To image hepatic venous entries, we directed the scan axis inside and cranially to the portal vein bifurcation plane. The sensor was displaced closer to the right parasternal line, and set under an acute angle to the anterior abdominal wall (the angle less than 30°) directed to the middle of the clavicle. If all three hepatic veins could not be imaged simultaneously, we examined them separately, and for this purpose the scan axis in the same plane was directed to the right or to the left till the lumen of the appropriate vessel was found. The described procedure is just the scheme that can undergo changes after extended hepatectomies depending on the liver location.

After pancreatoduodenectomies (PDE) we examined the bed of the resected head and a part of the body of the pancreas when the patient was in supine position. The sensor was placed in epigastrium, in transverse scan plane, parallel to the anterior abdominal wall, below the celiac axis level. The plane of scanning was directed down and to the right for better visualization of the resected head and duodenum area.

First we imaged ***the kidneys*** in cross section laterally in frontal view mounting a sensor along the anterior or midaxillary line, subcostally or an intercostal space higher, directing the scanning axis up and backward. Then we examined the kidneys from the back side in longitudinal sagittal plane along the scapular line, directing the scan axis on the contralateral scapula, and if necessary we turned the plane crosswise. We turned the sensor up and down to examine the poles, using respiratory mobility of the kidney for image enhancement.

Results and Discussion.

Normal echosemiotics of the liver after various types of resections. An ultrasonographer should conceive the volume of the operative intervention in each type of the hepatic surgery to understand the postoperative echopicture of the resected organ [5, 7]. The main ultrasound criterion in determining the resection type is the vascular structure of the liver, i.e., the number and location of hepatic veins, and this structure underlies the patients' division into three groups. After segment- and sectoral resections all three hepatic veins are positioned in the hepatic stump, after HHE — two veins, and after EHHE — one vein. We suggest indicating this criterion of resection volume determination as "the hepatic vein rule". We assessed the efferent vascular architectonics based on typical anatomical variants regardless the terminal part structure of the left and middle hepatic veins (they are joined by a common trunk, a common venous entry, or separate flow [8]), as it has no effect on postoperative echopicture.

In segment- and sectorectomy in the resected segment zone there can be observed deep (up to 4–5 cm) local retraction of the liver contour of semicircular shape, with no hepatic parenchyma image. Instead of parenchyma we could locate high-echogenic omentum tissue in the resection of IV and V segments or the retroperitoneal fat in VI segment resection (Fig. 1). Lobar branches of the portal vein hold their usual spatial configuration, though the segmental branch of the resected segment is absent.

The hepatic echopicture after sectorectomy is similar to a large extent, as the vascular architectonics of the liver does not undergo any significant changes: all hepatic veins are preserved; only the branch of the portal vein of the resected sector is removed. The size and location of the hepatic contour defect depend on the location of the resected segments. The consequences are least obvious after the left lateral sectorectomy, since the resection line is straight and does not cause any noticeable contour retraction, and frequently is overlapped by intensive echo-signals from the

Fig. 1. The condition after IV and V bisegmentation. Along the anterior hepatic surface, on the place of the resected segments there is a semicircular defect filled by echogenic omentum fat

adjacent stomach. The left hepatic vein is located at the periphery of the resection margin.

The arc-like contour retraction is seen on posterolateral surface of the liver, in place of VI and VII resected segments after the right posterolateral sectorectomy. In comparison with the echopicture after VI segment removal, this liver surface defect has more smooth semicircular shape, elongated backward to the diaphragm, and is always filled by retroperitoneal cellular tissue. The right hepatic vein is located along the resected margin in color flow mapping (Fig. 2). The subcostal scanning clearly shows the absence of the bifurcation of the right branch of the portal vein into anterior and posterior sectoral pedicles due to the posterior pedicle resection, but the portal vein division into the right and left branches remains unchanged.

The changes in hepatic echopicture are the most obvious after the right anteromedial sectorectomy due to the topical position of the removable V and VIII segments. The defect in the parenchyma on the place of the removed segments is large-sized and levels least of all in the following hypertrophy. The defect is filled by omentum, and well-defined on the anterior surface of the liver separating the left lobe from VI and VII segments located laterally and behind. All three hepatic veins are preserved in the hepatic stump, though the right and the middle hepatic veins are close to the resection margin, and separated by echogenic omentum fat. The anterior sectoral pedicle of the right branch of the portal vein is transected and not defined after the surgery.

It is difficult to distinguish the condition after anteromedial sectorectomy from that after mesohepatectomy, when IV segment is removed together with V and VIII segments, and if necessary — caudate lobe is removed too, and from multisegmental hepatectomy (IV, V, VI) as well, since after these operations a massive defect along the anterior surface of the liver is also visualized. The determining criterion is the absence of the middle hepatic vein, which is also transected in such types of resections. The bifurcation of the main trunk of the portal vein into the right and left branches remains, though on the right we resect the anterior sectoral branch, and on the left — the branch to IV segment. Sonographically, it does not result in noticeable changes in portal system structure and is found only when segmentary branches are studied.

The critical distinction of the hepatic echopicture after extended resections from that after segment- and sectorectomies is the reduced number of hepatic veins resected together with the removed part of the liver. The two remaining hepatic veins are located after HHE, one of them being situated along the resection margin, and the second — in the liver (Fig. 3).

The configuration of the portal vein and its branches is an additional criterion to confirm the hepatic resection type chosen. The intact portal vein is divided into the right and left branches at an angle close to 180° that is clearly seen in a subcostal scanning image. After extended resections with one of the lobar branches transected, only one vessel going

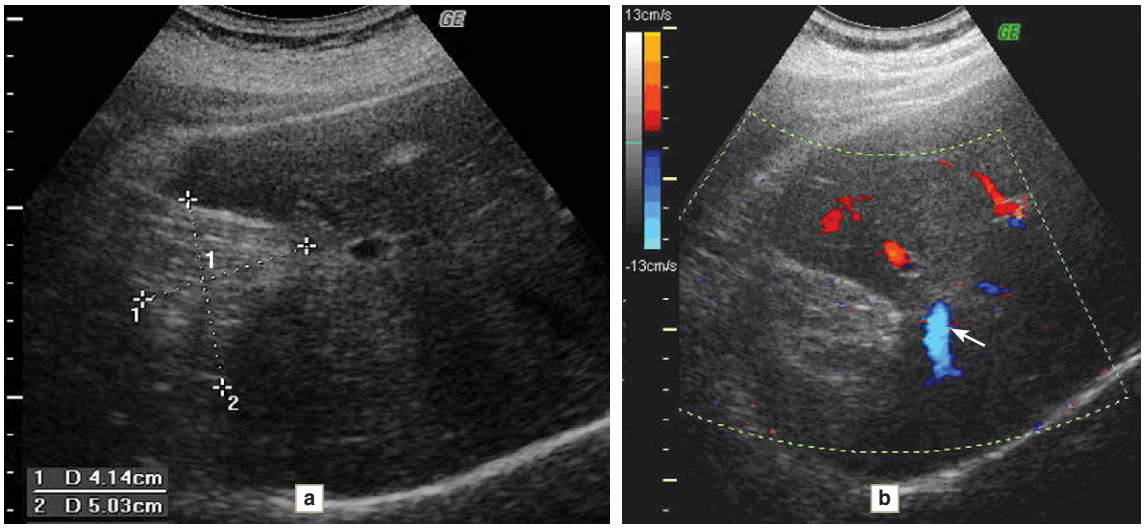

Fig. 2. The condition after the right posterolateral sectorectomy. Grey-scale scanning image (*a*) demonstrates a semicircular defect (*1*) filled by echogenic retroperitoneal fat along the hepatic contour, in the place of the resected VI and VII segments. Color flow mapping (*b*) shows the right hepatic vein (*2*) located close to the resection margin

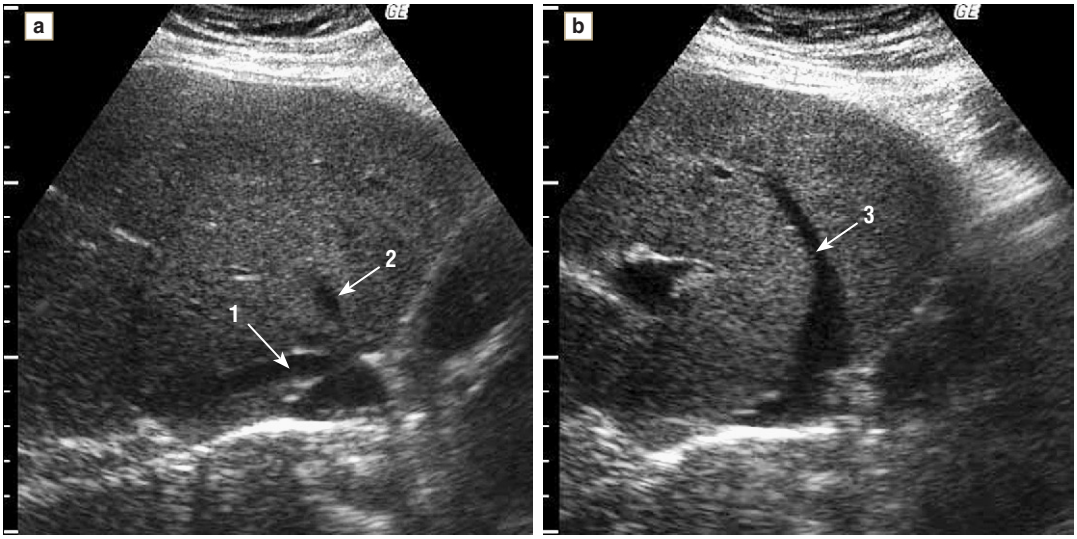

Fig. 3. The condition after the right HHE. Two hepatic veins are located in the hepatic stump (*a*): the middle hepatic vein along the resection margin (*1*), and the left — in the left lobe (*2*). When the scan plane is inclined (*b*), the left hepatic vein course is visible (*3*)

to the remaining lobe remains in the stump. Sonographically it is accompanied by the disappearance of the portal vein bifurcation, instead of which there can be seen the more or less evident curve along the vessel at the level it enters the remaining lobe.

The characteristic feature of the left lobe after the right HHE and EHHE is the spatial configuration of the left portal vein in the hepatic stump. It has an additional curve in the sagittal plane at an angle of 90° that corresponds to the anatomic course of the umbilical part, and terminates by the division into III and IV segmental branches. The echogenic round ligament of the liver goes from the top of the umbilical part to the inferior border of the liver, and near the hepatic base a segmental branch to II segment is located, the branch being the continuation of the left branch in subcostal plane. In left HHE the right portal vein has no curves in the stump, but is divided into the anterior and posterior branches of equal diameters supplying anteromedial and posterolateral segments with blood.

In EHHE not only the lobe is removed but also the adjoining medial segments of another lobe together with the middle hepatic vein, therefore after this operation only the right or the left hepatic vein is located in the stump. The echopicture of the portal system after the right EHHE shows the left portal vein to have no segmental branch to the resected IV segment. The umbilical part terminates not by the division into III and IV segmental branches, but it is continued by the only segmental branch of III segment. In left EHHE the anterior branch to V and VIII segments is resected, therefore, there is no the right portal vein bifurcation in the hepatic stump, and there can be located the posterior branch alone.

As compensatory hypertrophy develops, the liver enlarges, getting more round-shaped, and acute angles along the resection margin smooth out. The resected surface does not differ from other surfaces and has a well-defined and smooth contour. These features are characteristic of all resection types; therefore, the stump shape and the resection line location are just additional features in surgery type determining.

After the left HHE, the remaining right lobe preserves its typical anatomical place under the cupula of the diaphragm, and terminates at the left along the resection line, with no continuation in the left lobe (Fig. 4). After the right HHE, for the first postoperative months the remaining left lobe is in the epigastrium, but in compensatory hypertrophy it extends mainly to the right imitating the right lobe. However, it does not occupy all subphrenic space: the omentum, intestinal loops, hepatic flexure of the large intestine, and retroperitoneal fat can be seen at the left and laterally, on the place of the resected right lobe.

In early postoperative period after the right HHE one third of the patients has relocation of the left lobe to the right, which partially or completely takes more physiological place — under the right cupula of the diaphragm, and its

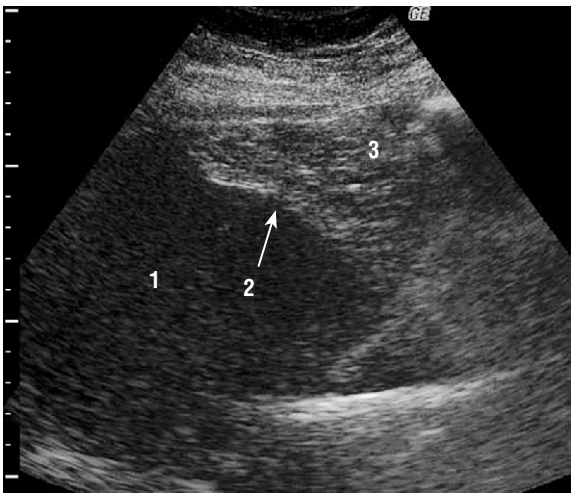

Fig. 4. The condition after the left HHE. There is the straight rupture of the liver parenchyma (*1*) along the resection line (*2*), and in the place of the resected left lobe echogenic omentum tissue is located (*3*)

place is taken by the omentum. Such a displacement of the left lobe under the right cupula of the diaphragm with 90–100° turning around the inferior vena cava is called rotation. In our situation, rotation was observed in 11 patients (22%) after EHHE. It did not have an effect on the postoperative course and life quality of the patients, though the hepatic stump position under the right cupula may result in misidentification of the resection side.

After the left EHHE the remaining VI and VII segments occupy posterolateral subphrenic space, and the resection plane has oblique, near-horizontal course. It can be differentiated in early postoperative period, since later it does not differ from the hepatic surface. The space of the resected left lobe is usually occupied by the omentum, partially — by the stomach and small intestinal loops.

Normal echosemiotics of the pancreas after pancreatoduodenectomy. As compared to other parenchymatous organs, the ultrasound assessment of the resected pancreas is the most difficult due to the technical challenges of its visualization due to a small size of the pancreatic stump, and oxygen-containing stomach and large intestine located behind, as well as the significant change of the spatial location of hollow organs as a result of the surgery. In our study we failed to image adequately the pancreatic area and its stump in 30% of the patients in early postoperative period after extended PDE due to air shielding in the intestine, and some limitations related to a postoperative suture. However, in late postoperative period we succeeded in visualizing the pancreatic stump in most patients owing to the technology we had developed.

In half of the cases the pancreas is located in epigastrium, behind the anastomozed isolated jejunal loop, which is adjacent to the body of the pancreas and bends the body along the right margin along the resection line that corresponds to the pancreatojejunal anastomosis zone (Fig. 5). In other patients a pancreatic stump is seen immediately behind the stomach that can be distinguished from a jejunal loop by a specific image of the wall with a typical five-layer structure. To differentiate difficult cases, the stomach filled by water can help: a patient is asked to drink water during the ultrasound procedure; since the resected stomach serves as an acoustic window to reveal the pancreas.

Fig. 5. The condition after extended PDE. Anastomozed jejunal loop (*1*) is closely adjoined to the body of the pancreas (*2*) and bends it along the resection line (*3*) along the right margin in the pancreatojejunal anastomosis zone

The assessment criteria of the pancreatic stump condition are its size, echogenicity, echostructure, contours and diameter of the major pancreatic duct. The pancreatic echogenicity after PDE does not change compared to the preoperative condition and corresponds to the age norm, or can be increased due to nonspecific diffuse changes. Antero-posterior dimension of the body of the pancreas is measured at aortal level, and should not exceed 20 mm. The important criterion is the diameter of Wirsung duct. Within a month after the operation it is permissible if the duct is slightly dilated (up to 3–4 mm) and then the lumen narrows (less than 2 mm), or there is the total imaging absence. In late postoperative the dilatation of Wirsung duct of more than 3 mm is considered to be a pathological sign, and the stricture development in pancreatojejunal anastomosis zone is suspected.

One more required element of a normal echopicture after extended PDE is aerobilia due to the air trapped in intrahepatic bile ducts through biliodigestive anastomosis. Most frequently it is moderately expressed, and hyperechogenic air-related signals are traced up to the level of the first parts of segmental biliary ducts, and less frequently — to the level of subsegmental parts, and the signals transmitting to the central parts of hepatic segments. The imaging of a biliodigestive anastomosis itself turns out to be impossible, though the common hepatic duct is defined at the level of porta hepatic as hyperechogenic linear structure.

Normal echosemiotics of the kidney after various types of resections. Partial nephrectomies are subdivided into planar (or transverse), wedge, and frontal. Every type of the operation has a specific echopicture of the resected kidney; and it is possible to determine the type of the resection by the stump shape and echostructure. Segmental planar resection is the most common organ-preserving operation, and performed if the predominant tumor location is the kidney pole. The volume of the operation is varied due to the tumor extension: there is removed the kidney pole, the third of the kidney with the upper or lower calex groups resected, or the whole upper or lower half of the kidney.

The echopicture of the residual part is characterized by the straight resection line directed perdendicularly to the longitudinal axis of the organ. Paranephric fat is adjacent to the resected surface (Fig. 6). The kidney boundary along the resection line is clearly seen due to the great difference in echogenicity of the kidney parenchyma and the adjacent fat. If more than one third of the kidney is resected, there can be observed blurred contour at the renal sinus level due to the equal fat echogenicity inside and outside the sinus.

Renal wedge resection is performed, when a tumor extends over more than two segments. Most commonly it occurs if the lesion is located on the renal edge. We performed wedge resection as atypical, since the pre-treatment of the arteries supplying only the affected renal area was impossible.

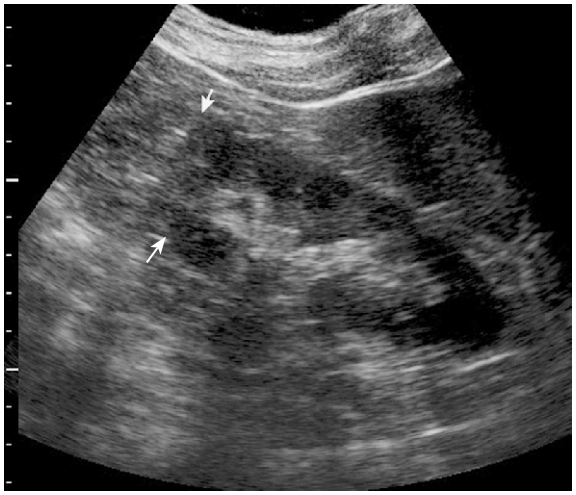

Fig. 6. The right kidney after planar resection of the lower pole (arrows indicate the resection line)

After wedge resection in renal parenchyma an echogenic scar remains; the scar extending from the outer edge to renal sinus and deforming the kidney contour. The scar is of small size, triangle shape, and homogeneous high-echogenic avascular structure with well-defined contours (Fig. 7). Its ultrasonic image resembles postinfarction cicatricial changes of parenchyma, with the greater deformation of the renal surface. The similar consequences are observed after wedge resection of mass lesions in kidney pole. In oblique scanning, echogenic fibrous tissue of the scar can be of round shape and mimic small subcapsular angiomyolipoma that resulted in false-positive ultrasound investigation in 2 patients at the place of their residence.

The echopicture of the kidney after frontal resection causes the major diagnostic problems due to an unusual shape of the organ, and can be misinterpreted as having nephrosclerotic manifestations due to the shallow thickness of the renal parenchyma in the operation zone. And, on the contrary, the remaining normal-sized part of the kidney can be considered as local deformation of the organ in tumor process.

We used frontal resection (modified by V.A. Atduev and V.A. Ovchinnikov [4]) for middle parts of the kidney if a tumor was localized on the anterior or posterior surface of one of the poles. The echopicture of early postoperative period is characterized by irregular thickness of the kidney in intact and resected parts. Frontal resection of the anterior or posterior parenchyma causes the decrease in the organ thickness in the form of a stair that is better defined in longitudinal sagittal scanning from the back side. The resected part junction is clearly seen, there is no fibrous capsule at this level, and echogenic paranephric fat is adjacent to the operated surface. Further the resection line becomes arc-shaped, with smoothed angles (Fig. 8). In the course of time the difference in renal thickness between the operated and intact parts decreases, the kidney contour being smoother.

Conclusion. Normal echosemiotics of the operated parenchymatous organs varies, and depends on the resection type. Therefore, an ultrasonographer should know the essence of the main operative measures to avoid diagnostic errors. The echopicture of hepatic stump enables to determine the surgery type, and can have three variants: the condition after segment oriented resection, portal or extended hemihepatectomy. The basic diagnostic criterion is the number and location of veins in the hepatic stump ("the hepatic vein rule") confirmed by the character of the portal vein branching. The echopicture after the right hemihepatectomy is the most difficult to assess due to the variable stump location due to its possible rotation. The assessment criteria of the pancreatic stump are its body size and the major pancreatic duct diameter, as well as spatial location of the anastomozed jejunal loop and the gastric remnant. US investigation enables to determine the nephrectomy type: planar, wedge, or frontal. A normal echopicture can be misinterpreted after frontal resection due to different parenchymal thickness in resected and preserved parts of the kidney.

Fig. 7. The left kidney after wedge resection of the middle third along the lateral surface (arrows indicate the resection zone)

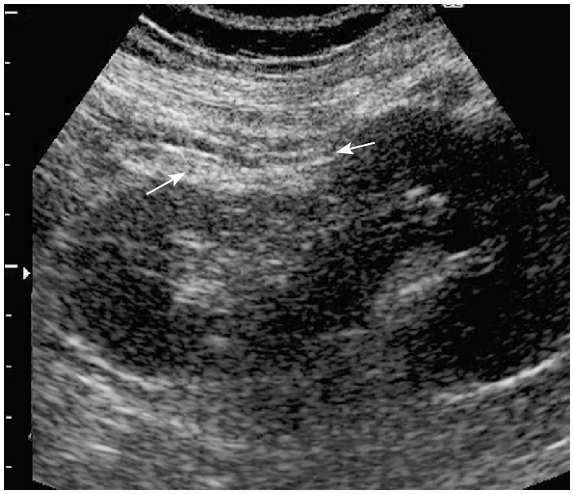

Fig. 8. The left kidney after frontal resection of the lower half, axial scanning from the back side (arrows indicate the resection zone)

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