Right Liver Resection Techniques for Advanced Alveolar Echinococcosis with Vascular Invasion

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The aim of the investigation was to analyze the techniques and results of right liver resections with vascular resections and reconstructions in advanced hepatic alveolar echinococcosis.

Material and Methods. The retrospective study included 12 patients with advanced alveolar echinococcosis of the right part of the liver and parasitic invasion of portal vein bifurcation, and/or inferior vena cava, and/or hepatic veins confluence. The mean age was 47.6±18.3 years (from 21 to 65 years, median 57). Extended right hemihepatectomy (Sg4–8) was performed in 10 (83.3%) cases, right hemihepatectomy (Sg5–8) in 2 (16.7%) cases. Sg1 was removed in 11 cases, additional nonanatomic resection of Sg2 and Sg3 was performed in 1 case. Normothermic resection was used in 10 patients, *in vivo in situ* hypothermic perfusion in 1 patient, and *ex vivo* resection in 1 patient. Arterial resection was necessary in 2 cases, portal vein resection in 9 cases, inferior vena cava resection in 8 cases. Inferior vena cava was reconstructed with a ePTFE-graft (1 case), autogenous vein graft (2), anastomosis (2), or by caval plasty (3).

Results. Hospital mortality was absent. Surgical complications (Grade IIIb–IVa, Clavien–Dindo) were observed in 5 cases, bile leakage (Grade C, ISGLS) in 2 cases. There were no vascular complications and post-hepatectomy liver failure. The patients stayed in the intensive care unit for 9.0±8.5 days (from 3 to 34 days, median 6) and total length of hospital stay was for 34.0±16.1 days on average (from 13 to 70 days, median 33). During 19-month median follow-up there was no recurrence of the disease.

Conclusion. Liver resection is the preferred treatment option and is feasible in the majority of patients with advanced alveolar echinococcosis in the absence of unresectable distant metastases, liver cirrhosis, Budd–Chiari syndrome and in the presence of technical possibility to preserve or reconstruct afferent and efferent blood circulation in the remnant liver.

Key words: alveolar echinococcosis; liver resection; hypothermic perfusion; total vascular exclusion..

Alveolar echinococcosis is helminthosis caused by *Echinococcus multilocularis* larvae, which passing into portal bloodstream from the bowel, are retained mainly by the liver and form tumor-like neoplasms. The difficulty of treating patients with liver alveolar echinococcosis, which has the signs of a slowly growing malignant tumor, is determined by the two features of the biology of this parasite: 1) infiltrative growth, the possibility of adjacent organs invasion and ability to metastazing; 2) absence of any symptoms of the disease at early stages, when liver resection does not present any problems. As a consequence, the diagnosis is usually established when the parasite reaches large sizes, and a standard radical resection of the liver often seems unfeasible: its feasibility in this disease is estimated by many authors as 35–50% [1–4]. Liver transplantation is regarded as a possible treatment option in a nonresectable process [5]. However, application of routine technologies used during transplantation (conservation, vascular reconstructions,

extracorporal circulation) in resection surgery provides the possibility to essentially widen the borders of alveococcosis resectability [6, 7].

At present, there is no clearly defined concept of "advanced alveococcosis". Previously, we supposed [8] that a key point of advancement definition is the necessity of choosing treatment strategy — assessment of resection feasibility and expediency of liver transplantation on the basis of the parasite invasion volume and involvement of portal vein (PV) bifurcation, inferior vena cava (IVC) and hepatic veins confluence. Since the most common location of alveolar echinococcosis is the right part of the liver, we want to present in this article our experience of right-sided liver resections in alveolar echinococcosis with invasion of the mentioned vascular structures, and to demonstrate surgical techniques used to achieve the radicalism of the treatment**.**

The aim of the investigation was to analyze the techniques and results of right liver resections with

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Table 1

Description of patients with advanced alveolar echinococcosis of the right part of the liver

No.	Age (years)/gender	Jaundice, PTCS prior to operation	Regional metastases	Remote metastases	Other diseases	Invasion volume (number of segments)	Artery invasion	PV invasion	HVC invasion	IVC invasion	Invasion of the adjacent structures
1	55/M	Yes	Yes	No	No	Sg4–8 + Sg1 (6)	No	Yes	Yes	Yes	Diaphragm
2	24/F	No	No	No	No	Sg5–8 + Sg1 (5)	No	No	No	Yes	Diaphragm, adrenal gland
3	65/F	Yes	Yes	Hilum of the right kidney, mesocolon	GIST-tumor of the jejunum	Sg4,6–8 + Sg1 (5)	CHA	Yes	No	Yes	Adrenal gland
4	21/F	Yes, PTCS	Yes	No	No	Sg4–8 + Sg1 (6)	No	Yes	No	Yes	No
5	25/M	No	No	No	No	Sg4,7,8 + Sg1 (4)	No	No	No	Yes	No
6	58/M	No	No	No	No	Sg6–8 (3)	No	No	No	Yes	Diaphragm
7	50/F	No	No	Left lung	No	Sg4–8 + Sg1 (6)	No	Yes	No	Yes	No
8	63/M	Yes, PTCS	No	No	Colon cancer	Sg4–6 + Sg1 (4)	No	Yes	No	No	No
9	63/F	Yes	Yes	No	No	Sg4–8 + Sg1 (6)	No	Yes	No	Yes	No
10	60/M	Yes, PTCS	Yes	No	No	Sg4–7 + Sg1 (5)	No	Yes	No	No	Adrenal gland
11	63/F	Yes, PTCS	Yes	No	No	Sg4–8 + Sg1 + Sg2,3 partially (8)	PHA	Yes	No	No	No
12	24/F	Yes	Yes	No	No	Sg4–7	No	Yes	No	No	No

N o t e: PTCS: percutaneous transhepatic cholangiostomy; PV: portal vein; HVC: hepatic veins confluence; IVC: inferior vena cava; CHA: common hepatic artery; PHA: proper hepatic artery.

vascular resections and reconstructions for advanced hepatic alveolar echinococcosis.

Materials and Methods

Patients. The present study included 12 patients (5 men and 7 women) at the age of 21 to 65 years (mean age 47.6±18.3 years, median 57) with advanced alveolar echinococcosis of the right part of the liver and parasite invasion of one or several following structures: PV bifurcation; IVC; hepatic veins confluence. In the period from October 2013 to November 2016 primary radical right-sided resections of the liver with various vascular reconstructions were performed in the Department of Organ Transplantation of the State Novosibirsk Regional Clinical Hospital. The study complies with the Declaration of Helsinki (the Declaration was passed in Helsinki, Finland, June 1964, and revised in October 2000, Edinburg, Scotland) and was performed following approval by the Ethic Committee of the State Novosibirsk Regional Clinical Hospital. Written informed consent was obtained from every patient including information on the usage of their data in the investigation purposes.

Description of patients and their preoperative data are presented in Table 1.

Preoperative examination and planning. Patients underwent preoperative examined by computed tomography (CT) using SOMATOM Emotion (Siemens, Germany) and Brilliance CT 64 (Philips, Holland) scanners. None of our patients required the use of combined CT and magnetic resonance imaging to confirm the diagnosis. The volume of the supposed remnant liver according to the results of CT volumetry was not taken into consideration. All patients underwent examinations of the brain and chest organs for remote metastases. Resectable remote alveolar echinococcosis metastases were found in 2 patients. Preoperative needle biopsy as a method of diagnosis verification was not used, in 1 case needle biopsy of the supposed remnant was performed to obtain more exact information on the liver parenchyma changes. Cirrhosis or Budd–Chiari syndrome were criteria for exclusion, in these cases transplantation was performed.

Mechanical jaundice with the level of total bilirubin over 200 µmol/L was indication to percutaneous transhepatic cholangiostomy which was performed to the 4 patients as the first stage prior to the main intervention. Dawson-Mueller (COOK Medical, USA) catheters were used for this purpose. Invasion of the biliary confluence with mechanical jaundice was not regarded as a criterion of alveolar echinococcosis advancement since it did not influence the decision "to make resection or transplantation".

The principal technical conditions of the

process resectability were: 1) feasibility of preservation or reconstruction of the afferent and/or efferent venous circulation in the remnant liver; 2) availability of arterial blood flow in the remaining segments and, consequently, the possibility of preservation or reconstruction of their arterial perfusion. Inability to realize these conditions served as an exclusion criterion, and in such cases transplantation was performed.

Surgical and anesthetic management. In all cases liver parenchyma was dissected with an ultrasonic CUSA EXcel dissector (Integra LifeSciences, USA). If venovenous bypass was required, extracorporal circulation was implemented by means of a Stöckert SPC centrifuge pump (Sorin Group, Germany).

All interventions were carried out under combined anesthesia on the basis of Sevoflurane (0.7–1.0 MAC) with a thoracic epidural analgesia according to Niemi and Breivik [9] with catheterization of the epidural space at the Th_6–Th_7 level.

Additionally to the noninvasive monitoring of standard parameters, intraoperative control of indices of central hemodynamics and volume status was conducted using PiCCO technology (PULSION Medical Systems, Germany). Acid-alkaline state, blood gas composition, lactate and activated clotting time were controlled by i-STAT analyzer (Abbott, USA). Hypothermia was prevented using Bair Hugger Model 775 system for patient warming (Arizant Healthcare Inc., USA). Blood reinfusion with the aid of C.A.T.S. plus device (Fresenius Kabi, USA) was performed during all interventions.

Types and parameters of the operations. Terminology of hepatic anatomy and resections (Table 2) was used in compliance with the Brisbane 2000 nomenclature [10]. The succession of intraoperative procedures was determined on the basis of the visualization data when interventions were being planned. In none of the cases the surgical strategy was changed and resection abandoned in favor of transplantation. Extended right hemihepatectomy (Sg4–8) was performed in 10 cases, right hemihepatectomy (Sg5–8) in 2 cases, Sg1 being included into the specimen in 11 cases, in one case the plane of resection was displaced to the left lateral sector and, as a result, Sg2 and Sg3 were resected nonanatomically. All resections were accomplished in R0 variant. Resection of the diaphragm and/or right adrenalectomy *en bloc* with the removable part of the liver were performed in 5 patients with the invasion of the parasitic tumor in the adjacent organs. Simultaneous interventions in other organs were carried out in 2 patients: in 1 case it was resection of the small intestine for GIST-tumor, in 1 case left hemicolectomy for moderately differentiated adenocarcinoma.

It should be noted that the principal factor determining the type of resection (normo- or hypothermic) was not the invasion of the retrohepatic segment of the IVC, but rather the possibility of the vascular control of the afferent and efferent blood flow in the remnant liver. It

was the retention of the remnant that served the factor determining the patient safety, and in this connection the description of each technique used is of interest.

Normothermic resections were performed in 10 patients in the following situations: 1) invasion of the left hepatic vein was absent, i.e. its extraparenchymatous isolation was possible; 2) Rex sinus invasion was absent, i.e. there was a possibility of its isolation and preservation of the afferent perfusion of the entire left lateral sector. The succession of actions was as follows.

Stage 1. Mobilization of the diaphragmatic surface of the left lateral sector with isolation of the left hepatic vein or the common trunk of the middle and left hepatic veins — this provided the control of venous outflow from the remaining part of the liver.

Stage 2. Mobilization of the hepatoduodenal ligament elements to provide the control of the afferent blood flow of the whole liver.

Stage 3. Mobilization of the artery and PV (left branch or Rex sinus) of the supposed remnant to provide the control of its afferent blood flow. As a rule, isolation of the left hepatic artery was not difficult owing to its extreme left position in the ligament or availability of anatomical variant of branching from the left gastric artery, and was possible in 9 of 10 cases. Isolation of PV bifurcation was feasible only in 3 cases of 10, in the rest cases PV bifurcation was invaded by the parasite.

Stage 4. Creation of an isolated arterial blood supply of the remnant part of the liver — in 9 cases of 10 this stage consisted in the transection of the right hepatic artery, in 1 case (invasion of the common hepatic artery in a patient with standard arterial anatomy) arterial perfusion of the remaining left lateral sector was restored using a reversed autogenous vein graft from the great saphenous vein in the "splenic artery — artery of the left lateral segment" position.

Stage 5. Creation of the isolated portal blood supply of the remaining part of the liver — in 3 cases of 10 this stage consisted in the transection of the right PV, in 2 cases tangential resection of PV was performed with its plasty by suturing the generated defect in the transverse direction, in 5 cases it was circular PV resection with its reconstruction by anastomosis in 4 patients and autogenous vein graft from the internal jugular vein in the "PV — Rex sinus" position in 1 patient.

Stage 6. Hanging-maneuver and dissection of the parenchyma (middle vein was treated at the entry when S4 was removed) — this stage was completed with obtaining a viable liver fragment with its own blood circulation isolated from the removed liver segments.

Stage 7. Mobilization of the right part of the liver and manipulations with retrohepatic segment of IVC. Separation of IVC from the affected part of the liver was feasible in 3 from 10 cases and was completed by the transection of the right hepatic vein with the following removal of the specimen. In the rest 7 cases, due to parasitic invasion, retrocaval mobilization

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Technical features and parameters of the operations performed

No.	Invasion volume (number of segments)	Resection volume (number of removed segments)	Resection, reconstruction of the arteries	Resection, PV reconstruction	Resection, IVC reconstruction	VVB	Preservation	Biliary reconstruction	Other organ interventions
1	Sg4–8 + Sg1 (6)	ERHHE + Sg1 (6)	No	Tangential, plasty	Circular, ePTFE-graft	Yes	in vivo in situ	BDA	Diaphragm resection
2	Sg5–8 + Sg1 (5)	RHHE + Sg1 (5)	No	No	Circular, autogenous venous graft	Yes	No	No	Diaphragm resection, adrenalectomy
3	Sg4,6–8 + Sg1 (5)	ERHHE + Sg1 (6)	CHA resection, prosthetic replacement of LLS artery with autogenous venous graft	Circular, anastomosis	Circular, autogenous venous graft	Yes	No	BDA	Adrenalectomy, jejunum resection
4	Sg4–8 + Sg1 (6)	ERHHE + Sg1 (6)	No	Circular, autogenous venous graft	Tangential, plasty	No	No	BDA	No
5	Sg4,7,8 + Sg1 (4)	ERHHE + Sg1 (6)	No	No	Tangential, plasty	No	No	No	No
6	Sg6–8 (3)	RHHE (4)	No	No	Tangential, plasty	No	No	No	Diaphragm resection
7	Sg4–8 + Sg1 (6)	ERHHE + Sg1 (6)	No	Tangential, plasty	Circular, anastomosis	No	No	No	No
8	Sg4–6 + Sg1 (4)	ERHHE + Sg1 (6)	No	Circular, anastomosis	No	No	No	BDA	Left-sided hemicolectomy
9	Sg4–8 + Sg1 (6)	ERHHE + Sg1 (6)	No	Circular, anastomosis	Circular, anastomosis	No	No	BBA	No
10	Sg4–7 + Sg1 (5)	ERHHE + Sg1 (6)	No	Tangential, plasty	No	No	No	BBA	Adrenalectomy
11	Sg4–8 + Sg1 + Sg2,3 partially (8)	ERHHE + Sg1 (6) + resection Sg2,3	PHA resection, reconstruction of segment Sg3 artery	Circular, prosthetic replacement of Rex sinus with autogenous venous graft	No	Yes	ex vivo	BDA	No
12	Sg4–7	ERHHE + Sg1 (6)	No	Circular, anastomosis	No	No	No	BBA	No

N o t e. PV: portal vein; IVC: inferior vena cava; VVB: venovenous bypass; ERHHE: extended right hemihepatectomy (Sg4–8); RHHE: right hemihepatectomy (Sg5–8); CHA: common hepatic artery; LLS: left lateral sector; PHA: proper hepatic artery; BDA: biliodigestive anastomosis; BBA: biliobiliary anastomosis.
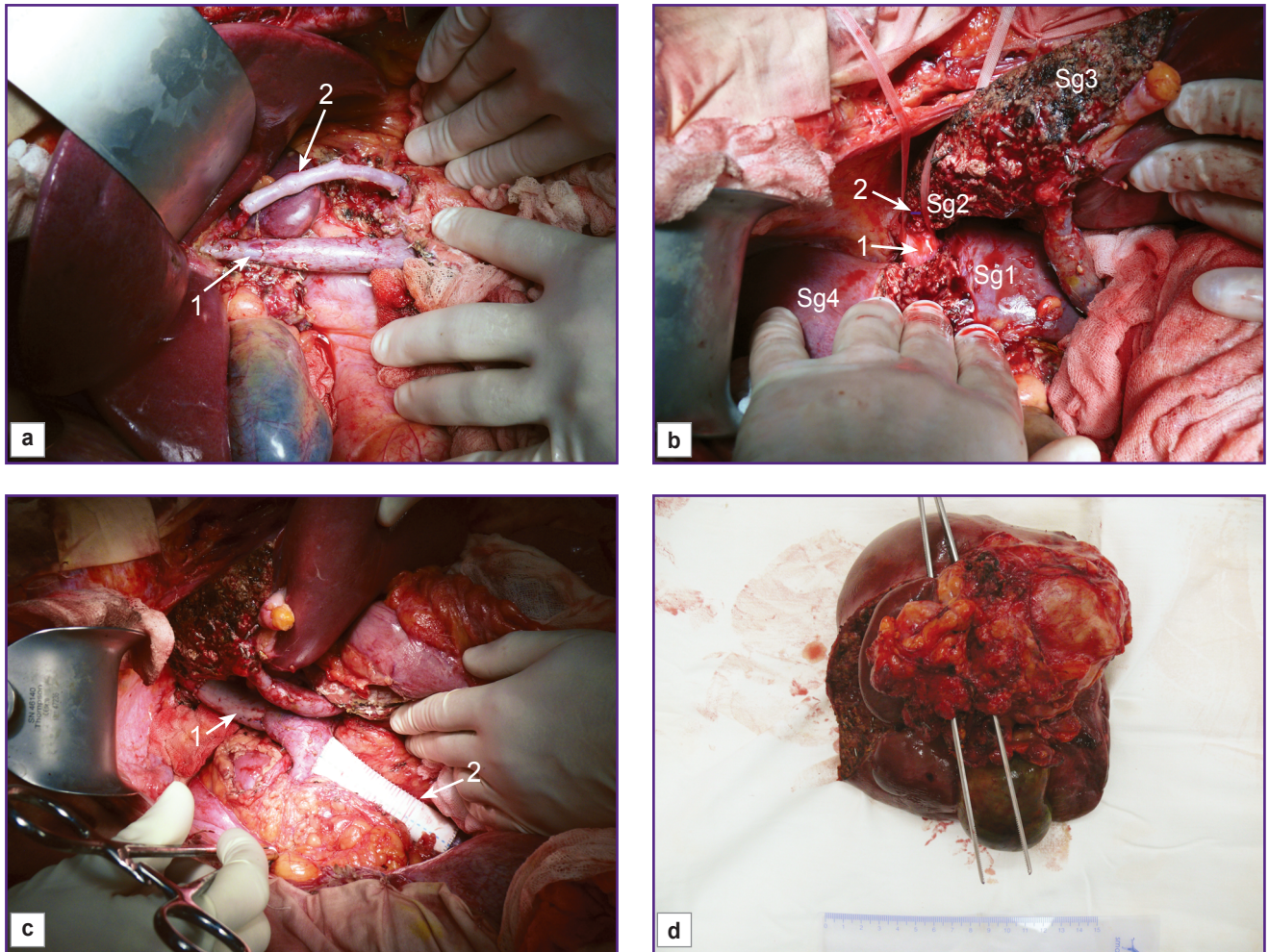
Figure 1. Normothermic resection in a female patient with alveolar echinococcosis of Sg4, 6–8 + Sg1 with invasion in portal hilum and retrohepatic segment of the inferior vena cava (IVC): (a) reconstruction of the afferent perfusion of the remaining left lateral sector is completed (*1* — portoportal anastomosis between the left portal vein and the main trunk of the portal vein, *2* — autogenous venous graft from the splenic artery to Sg2, 3 artery); (b) splitting on the preserved blood flow is completed, remnant is fully isolated from the removable part of the liver (*1* — IVC, *2* — entry of the left hepatic vein); (c) the final appearance of the liver after removal of segments Sg4, 6–8 + Sg1 and reconstruction of IVC (*1* — transferred autogenous venous graft from infrarenal IVC segment, *2* — 20 mm ePTFE-graft in the infrarenal position); (d) macropreparation of the removed part of the liver (forceps branches are introduced in the IVC)

and crossclamping of IVC with two clamps (the first clamp was applied infrahepatically, the second one retrohepatically below the entry of the left hepatic vein) were performed, the outflow from the remaining liver fragment was not impaired thereby. Then the specimen was removed *en bloc* with part of the retrohepatic IVC segment. In 3 cases of tangential resection IVC plasty was performed by suturing in oblique-transverse direction without using venous patches in any case. In 2 cases of circular resection with a less than 5 cm diastasis between transacted ends, the integrity of IVC was restored by means of cavacaval anastomosis. In the rest 2 cases of circular resection, prosthetic replacement of IVC was performed using transferred autogenous venous graft from infrarenal IVC segment under venovenous bypass conditions according to the scheme "femoral vein → axillary vein". IVC occlusion was not accompanied by hemodynamic instability in any of the cases. Example of normothermic resection is presented on Figure 1.

Hypothermic resection in vivo in situ was accomplished to 1 patient with parasitic invasion of hepatic veins confluence. Custodiol-HTK solution in 5 L volume with perfusion via PV was used for liver preservation. All manipulations (PV resection, IVC resection, parenchyma separation and vascular reconstruction) were performed under venovenous bypass according to the scheme "femoral + portal
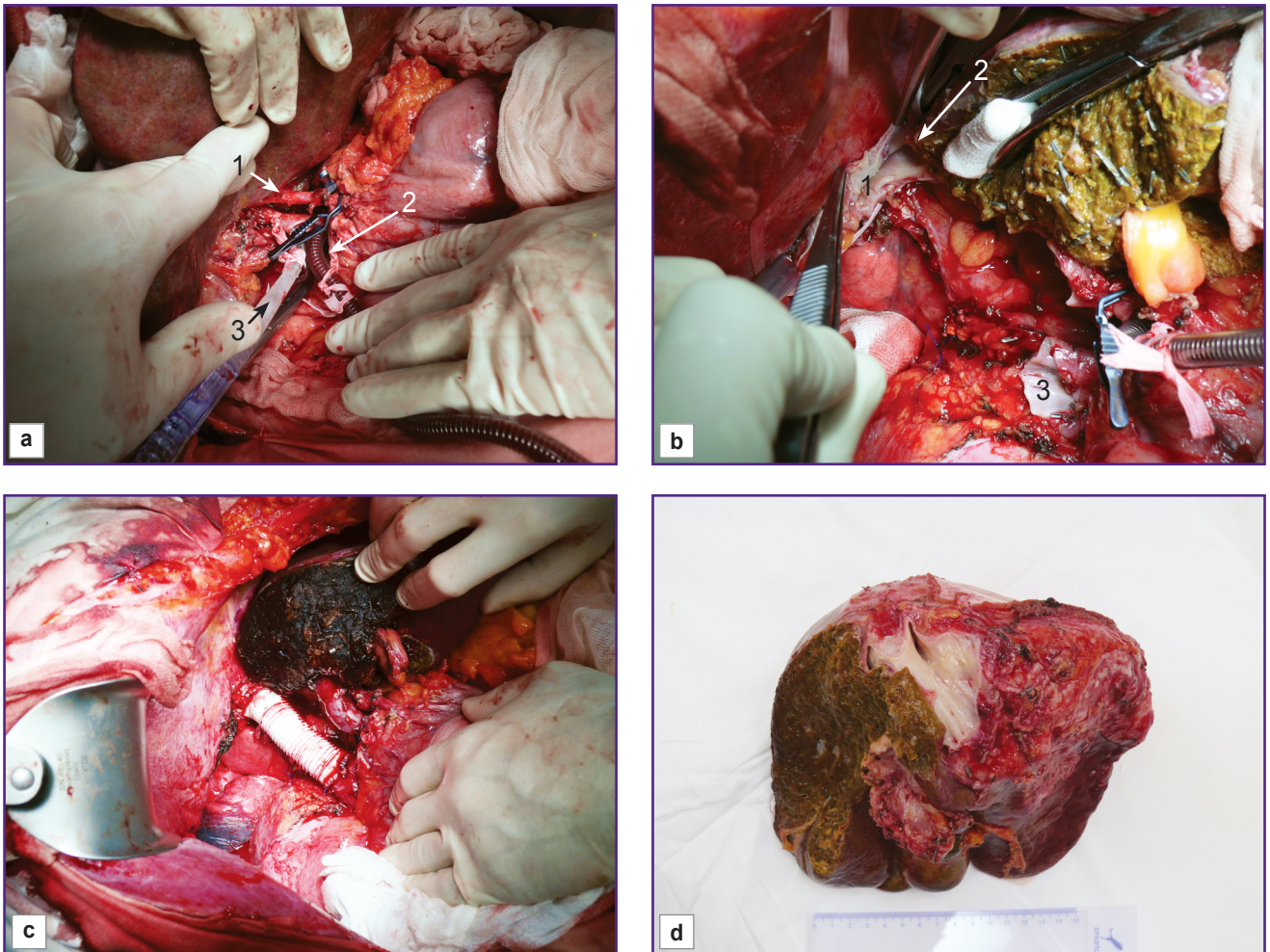
Figure 2. Hypothermic resection *in vivo in situ* in a male patient with alveolar echinococcosis of Sg4–8 + Sg1 with the invasion of the portal hilum, retrohepatic segment of the inferior vena cava (IVC) and hepatic veins confluence: (a) beginning of hypothermic perfusion of the liver after its total vascular isolation (*1* — left hepatic artery, *2* — portal cannula of the venovenous bypass contour, *3* — perfusion cannula with Custodiol-HTK solution); (b) Sg4–8 + Sg1 with IVC are removed (*1* — suprahepatic segment of IVC, *2* — left hepatic vein, *3* — infrahepatic segment of IVC); (c) final appearance after completion of the vascular reconstruction and remnant reperfusion; (d) macropreparation of the removed part of the liver

veins → axillary vein”; duration of liver ischemia was 180 min. Retrohepatic IVC segment was replaced by 20 mm ringed ePTFE-graft. Intraoperative photographs of this intervention are presented on Figure 2.

Hypothermic resection ex vivo was carried out to 1 patient with alveolar echinococcosis of Sg4–8 + Sg1 and peripheral invasion of Sg2, 3 with Rex sinus involvement due to the necessity of reconstructing the afferent blood flow separately for Sg2 and Sg3. In this case there were successively performed mobilization of the hepatic-duodenal ligament elements, liver mobilization, mobilization of the retrohepatic IVC segment and hepatectomy without resection of the latter. The liver was perfused *ex vivo* with Custodiol-HTK solution (5 L) via PV. Then dissection of the parenchyma along the plane running through Sg2, 3 was done on the back table using ultrasound dissector, and an unaltered fragment

of the left lateral sector was obtained with separate portal veins and arteries of Sg2 and Sg3 and common outflow via left hepatic vein. Arterial reconstruction was performed: the ends of the resected Sg3 artery (Sg2 artery was not resected) were anastomosed. Rex sinus was reconstructed using autogenous venous graft (a fragment of the internal jugular vein). The remnant was reimplanted in the orthotopic position. During back-table manipulations venovenous bypass was initiated according to the scheme “PV → IVC”. The time of cold ischemia and secondary warm ischemia was 240 and 30 min, respectively. Intraoperative photographs of this intervention are presented on Figure 3.

Biliary reconstruction was required in 8 cases, in 3 patients it was done in the form of biliobiliary anastomosis with the common bile duct, in 5 patients in the form of biliodigestive anastomosis with Roux-en-Y loop.
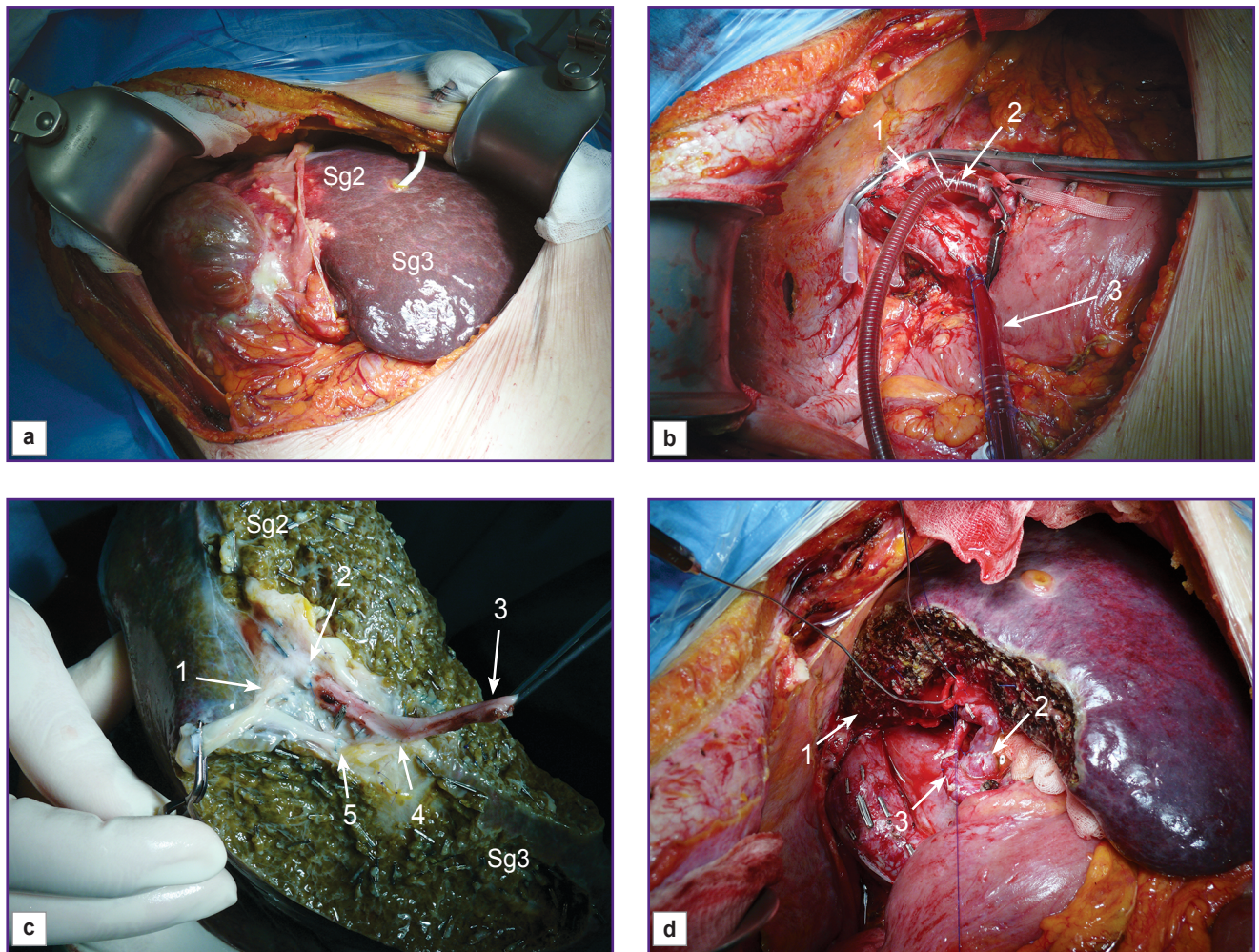
Figure 3. Hypothermic resection *ex vivo* in a woman with alveolar echinococcosis of Sg4–8 + Sg1 with marginal invasion of Sg2, 3 and invasion of portal hilum: (a) general appearance of the liver after laparotomy (cholangiostoma formed through the duct of Sg2 is seen); (b) hepatectomy is performed, procedure of venovenous "PV (portal vein) → IVC (inferior vena cava)" bypass is initiated (*1* — a clamp on the common trunk of the median and left hepatic veins, *2* — portal cannula of the venovenous bypass, *3* — caval cannula of the venovenous bypass); (c) resection and vascular reconstruction are completed on the back-table (*1* — artery of Sg2, *2* — PV anastomosis of Sg2 with autogenous venous graft, *3* — autogenous venous graft from internal jugular vein, *4* — PV anastomosis of Sg3 with autogenous venous graft, *5* — restored artery of Sg3); (d) the left lateral sector is reimplanted in orthotopic position (*1* — hepaticocaval anastomosis, *2* — portal anastomosis, *3* — arterial anastomosis, probes are introduced into the combined duct orifices of Sg2 и Sg3)

Specific therapy and postoperative follow-up. All patients received anticoagulant treatment with low-weight-molecular heparins in the dose of 40–60 anti-Xa/kg/day till the activation time but for not less than 10 days, unfractionated heparin was not used. Continuous antiaggregant therapy was administered to only 1 patient with implanted IVC ePTFE-graft. Patients undergone biliary reconstructions received ursodeoxycholic acid in the dose of 750–1,500 mg/day. Adjuvant chemotherapy with a continuous course of albendazole in the dose of not more than 800 mg/day was recommended to all patients during 6 months after the discharge from the hospital.

Dynamic out-patient follow-up was carried out with obligatory CT examination at 3, 6 and 12 months following the operation and thereafter once a year.

Hospital postoperative complications. Stratification of the postoperative complications was done in compliance with Clavien–Dindo classification [11]. The rate of postresection hepatic failure [12], bleeding [13] and biliary complications [14] was assessed with the help of ISGLS criteria.

Statistics. The data were analyzed using SPSS Statistics, v. 20 and presented as mean ± standard deviation (M±SD), median (Me) was calculated for variables, and minimal (min) and maximal (max) values were indicated.

Results

Direct results of the operations are presented on Figure 3. The quantity of the removed segments varied from 4 to 6 (median 6) and amounted on average to 5.8±0.6 (Table 3). Duration of the operations ranged from 360 to 1,080 (median 562) min and amounted on average to 680.0±248.8 min. Intraoperative blood loss varied from 500 to 4,200 (median 1,900) ml and was 2,008.0±1,900.0 ml on average.

Neither postresection bleedings nor postresection liver failure were fixed. None of the patients required replacement renal therapy or other efferent methods of treatment. Postoperative complications developed in 5 patients. The right-sided hydrothorax, requiring the pleural drainage, was revealed in 3 patients, in 1 case subdiaphragmatic abscess was drained percutaneously. In 2 patients bile leakage was noted due to the incompetence of cholangio-jejunoanasomosis (Grade C as per ISGLS), in both cases relaparotomy and suturing of the anastomosis defects were accomplished on day 13 and 15 after the operation. Incompetent anastomoses were not detected after bilibiliary reconstructions. On day 4 after the operation 1 patient developed encephalopathy not caused by liver failure and acute blood circulation impairment with depression of consciousness to GCS7 according to the Glasgow Coma Scale, demanding intubation and respiratory support for 13 days.

Patients stayed in the intensive care unit for 9.0±8.5 days on average (from 3 to 34 days, median 6), the total length of hospital stay after the operation amounted to 34.0±16.1 days on average (from 13 to 70 days, median 33). In-hospital mortality was not registered.

Remote results were obtained by following up all patients for 2–39 months (median 19), recurrence of the disease being noted in none of the patients. Atypical resection of the upper lobe of the left lung for alveolar echinococcosis metastasis was performed in one patient 5 months after liver resection. Thrombosis of the ePTFE-graft without disturbance of the outflow from the liver and clinically significant IVC syndrome was registered in 1 patient 21 months after the hypothermic resection *in vivo in situ* with the replacement of IVC by ePTFE-graft.

Discussion. A radical surgical elimination of the parasitic tumor is the main aim of treating patients with alveolar echinococcosis [1, 14]. PNM classification of alveolar echinococcosis suggested by the World Health Organization and recommended for staging, and therefore, for determining the tactics of treatment, admits the possibility of surgical treatment mainly in patients with peripheral or monolobe localization of the parasite without involvement of the main veins [14]. But due to asymptomatic process, the majority of patients have advanced forms of the disease, when standard liver resection is unlikely to be feasible. Therefore, some authors accept cytoreductive resections in the presence of vascular invasion [15, 16]. However, if there is a feasibility of performing transplantations in the centers specializing in hepatobiliary surgery, and consequently, applications of transplantation technologies for resections, in the majority of clinical situations the possibility of radical treatment of these patients may be provided [8, 17, 18].

Liver resection in advanced alveococcosis must be not only radical but also safe for a patient. The key

Table 3
Results of the operations

No.	Resection volume (number of the removed segments)	Operation time (min)	Blood loss (ml)	Stay in ICU (days)	Hospital stay (days)	Complications, Clavien–Dindo	PRHF, ISGLS	Hemorrhage, ISGLS	Bile leakage, ISGLS	Outcome (follow-up period (month))
1	ERHHE + Sg1 (6)	870	2,500	14	42	Grade IIIa	—	—	—	Alive, no recurrence (39)
2	RHHE + Sg1 (5)	540	4,200	5	37	Grade IIIa	—	—	—	Alive, no recurrence (28)
3	ERHHE + Sg1 (6)	1,050	1,500	6	25	—	—	—	—	Alive, no recurrence (26)
4	ERHHE + Sg1 (6)	1,080	3,500	10	50	Grade IIIb	—	—	Grade C	Alive, no recurrence (21)
5	ERHHE + Sg1 (6)	560	2,400	6	22	—	—	—	—	Alive, no recurrence (19)
6	RHHE (4)	555	2,300	4	33	Grade IIIa	—	—	—	Alive, no recurrence (19)
7	ERHHE + Sg1 (6)	390	500	3	13	—	—	—	—	Alive, no recurrence (18)
8	ERHHE + Sg1 (6)	690	800	7	45	—	—	—	—	Alive, no recurrence (10)
9	ERHHE + Sg1 (6)	565	3,700	6	22	—	—	—	—	Alive, no recurrence (6)
10	ERHHE + Sg1 (6)	390	700	6	33	Grade IIIa	—	—	—	Alive, no recurrence (5)
11	ERHHE + Sg1 (6) + resection Sg2, 3	970	1,500	34	70	Grade IVa	—	—	Grade C	Alive, no recurrence (3)
12	ERHHE + Sg1 (6)	500	500	3	17	—	—	—	—	Alive, no recurrence (2)

N o t e. ICU: intensive care unit; PRHF: postresection hepatic failure; ERHHE: extended right hemihepatectomy (Sg4–8); RHHE: right hemihepatectomy (Sg5–8).

safety factors are normal state of the perspective liver remnant and possibility of its blood circulation control, and the philosophy of alveolar echinococcosis resection surgery is believed by us to actually consist in the resection and preservation of the healthy part of the liver and the following removal of the part affected by the parasite. It will not be an overestimation to say that the problem of postresection hepatic failure is not vital for the surgery of this disease, since the very growth of the parasite results in vicarious hypertrophy of the functioning liver parenchyma, the volume of which is not diminished much even after very extensive resections. It is only important to preserve its quality while performing the operation.

The technique used by us in normothermic resections is similar to the "no-touch" technique suggested by Neuhaus et al. [19] for improvement of the results of the extended right-sided resections in perihilar cholangiocarcinoma and consisting in performing resection and PV reconstruction without isolation of its bifurcation prior to the beginning of parenchyma dissection. We used this method not for radicalism, but on the grounds of the safe creation of afferent liver remnant perfusion, as the attempts of isolating the right portal vein in case of PV bifurcation invasion by the parasite may result in serious hemorrhage.

It should be noted that manipulations with IVC in case of the supposed invasion require obligatory vascular control. The first attempt of liver resection with IVC prosthetic replacement [20] and the first successful operation of this kind [21] was implemented by the team which was a pioneer in liver transplantation. Standard total vascular exclusion of the liver includes mobilization of the whole liver together with the retrohepatic IVC segment and sequential clamping of the vessels in the following order: 1) hepatic artery and PV; 2) infrahepatic IVC; 3) suprahepatic IVC [22]. This maneuver is necessary when hepaticocaval confluence is involved in the process, it requires preparation and should be anticipated as the catastrophe may develop in the course of resection. Total vascular exclusion for more than 60 min under normothermic conditions is associated with the worse tolerance to ischemia and worse results, hypothermal perfusion with preserving agents solves the problem of ischemic reperfusion liver damage [23]. Hypothermic liver resection can be done in the following variants: *in vivo in situ, in vivo ex situ,* and *ex vivo* [24].

In our cohort, the indication to a single performed hypothermic resection *in vivo in situ* was simultaneous invasion of PV bifurcation and hepatic veins confluence. Analyzing this case retrospectively and taking into consideration the gained experience of transplanting liver fragments from the living donors, another scenario of performing this operation can be suggested — without hypothermic perfusion, i.e. reconstruction of the PV as the first stage, then parenchyma dissection with preserved blood flow, standard total vascular exclusion and resection of the hepatic veins confluence, and

finally, IVC reconstruction with restoration of the blood flow in the remnant after formation of the upper caval anastomosis. This approach, aimed at minimization of the liver ischemia time and IVC occlusion time, was described in detail by Hemming et al. [25].

Hypothermic resection was considered justified in the situation with massive alveolar echinococcosis extending to the perspective left lateral sector. The necessity of a complicated reconstruction of the afferent perfusion of Sg2 and Sg3 separately was the reason for preservation and resection *ex vivo*. Such indication is regarded as one of the possible and is presented in the largest presently published series of autotransplantations for alveolar echinococcosis, including 15 patients with 6.7% hospital lethality, absence of recurrences in 86.7% of patients and median follow-up for 21.6 months [26].

Conclusion. Radical treatment of liver alveolar echinococcosis is feasible if nonresectable remote metastases are absent. Liver resection is a preferable therapeutic option and is feasible in the majority of patients with advanced alveolar echinococcosis in the absence of cirrhosis, Budd–Chiari syndrome and in the presence of technical possibility of preservation/reconstruction of the afferent and efferent blood circulation in the perspective liver remnant. Noncompliance with these conditions is the indication for liver transplantation. The treatment tactics and intervention planning must be determined on the basis of the preoperative examination findings, and interventions performed in specialized centers routinely performing both resections and transplantations.

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