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МУНДАРИЖА | СОДЕРЖАНИЕ | CONTENT

MARKERS OF HEPATIC FUNCTION, INFLAMMATION, AND ENDOTHELIAL DYSFUNCTION IN THE LONG-TERM PERIOD AFTER LIVER DONATION IN LIVING-RELATED TRANSPLANTATION

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XaybullinaZ.R., Ismailov S.I., Tairova L.S., Bondarchuk M.V., Abdushukurova S.E., Abdullayeva S.D., Payziyeva N.R., Usmanov A.A., Fayzullayev O.A., Tuksanov E.A., Shamsiyeva N.R.

Republican Specialized Scientific and Practical Medical Center of Surgery named after Academician V. Vakhidov.

Abstract

Objective. To assess liver panel parameters, markers of subclinical inflammation, hemostasis, and endothelial dysfunction in living liver donors in the long-term period after donor hemihepatectomy.

Materials and Methods. The study included 131 living related liver donors. Of these, 120 donors were operated on at a single center and followed up preoperatively and at 12, 24, and 36 months after donation; 11 donors operated abroad were examined at 12–96 months post-donation. Laboratory evaluation comprised complete blood count, liver and metabolic panels, coagulation tests, inflammatory markers (C-reactive protein, interleukin-6), and markers of endothelial dysfunction (von Willebrand factor, homocysteine). Statistical analysis was performed using MedCalc v23.0.8.

Results. Basic metabolic parameters, hemoglobin levels, platelet count, and routine coagulation tests remained within reference ranges throughout follow-up. However, from 12 months after donation, a significant increase in leukocyte and lymphocyte counts was observed ($p<0.05$). Markers of subclinical inflammation demonstrated progressive elevation, with significant increases in IL-6, C-reactive protein, and fibrinogen at 24 and 36 months. From 24 months onward, laboratory signs of cholestasis emerged, including elevated total and direct bilirubin and alkaline phosphatase. Markers of endothelial dysfunction showed a sustained increase beginning 12 months after donation.

Conclusion. In the long-term period after liver donation, donors develop signs of subclinical inflammation, endothelial dysfunction, and progressive cholestatic changes despite preserved basic laboratory parameters, highlighting the need for long-term targeted monitoring.

Keywords: living liver donation, hemihepatectomy, subclinical inflammation, endothelial dysfunction, cholestasis.

МАРКЕРЫ ПЕЧЕНОЧНОЙ ПАНЕЛИ, ВОСПАЛЕНИЯ И ЭНДОТЕЛИАЛЬНОЙ ДИСФУНКЦИИ В ОТДАЛЁННОМ ПЕРИОДЕ ПОСЛЕ ДОНОРСТВА ПЕЧЕНИ ПРИ ЖИВОЙ РОДСТВЕННОЙ ТРАНСПЛАНТАЦИИ

Хайбуллина З.Р., Исмаилов С.И., Таирова Л.С., Бондарчук М.В., Абдушукурова С.Э., Абдуллаева С.Д., Пайзиева Н.Р., Усманов А.А., Файзуллаев О.А., Туксанов Э.А., Шамсиева Н.Р.

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Аннотация

Цель. Оценить параметры печёночной панели, маркёры субклинического воспаления, системы гемостаза и эндотелиальной дисфункции у живых родственных доноров печени в отдалённом периоде после донорской гемигепатэктомии.

Материалы и методы. В исследование включён 131 родственный донор доли печени. Из них 120 доноров были оперированы в одном центре с последующим наблюдением до операции и через 12, 24 и 36 месяцев после донорства; ещё 11 доноров, оперированных за рубежом, обследованы в сроки 12–96 месяцев после донорства. Лабораторное обследование включало общий анализ крови, показатели печёночной и базовой метаболической панели, коагулограмму, маркёры воспаления (С-реактивный белок, интерлейкин-6) и эндотелиальной дисфункции (фактор Виллебранда, гомоцистеин). Статистический анализ выполнен с использованием MedCalc v23.0.8.

Результаты. Показатели базового метаболического профиля, уровень гемоглобина, количество тромбоцитов и скрининговые тесты коагулограммы сохранялись в пределах референсных значений. Начиная с 12 месяцев после донорства отмечалось достоверное увеличение числа лейкоцитов и лимфоцитов ($p<0,05$). Маркёры субклинического воспаления (ИЛ-6, СРБ, фибриноген) прогрессивно повышались через 24 и 36 месяцев. С 24 месяцев выявлялись лабораторные признаки холестаза — повышение общего и прямого билирубина и активности щелочной фосфатазы. Маркёры эндотелиальной дисфункции демонстрировали устойчивое нарастание с 12 месяцев наблюдения.

Заключение. В отдалённом периоде после донорства печени у доноров формируются признаки субклинического воспаления, эндотелиальной дисфункции и прогрессирующего холестаза при сохранности базовых

лабораторных показателей, что обосновывает необходимость длительного целенаправленного мониторинга.

Ключевые слова: живое донорство печени, гемигепатэктомия, субклиническое воспаление, эндотелиальная дисфункция, холестаз.

JIGAR PANEL MARKERLARI, YANGILISHI VA ENDOTELIAL DISFUNKSIYASI JIGAR DONATIONDAN KEYIN UZOQ MUDDATLI DAVRANIYDA TILIGA BAĞLI TRANSPLANTATSIYADA

Xaybullina Z.R., Ismailov S.I., Tairova L.S., Bondarchuk M.V., Abdushukurova S.E., Abdullaeva S.D., Paizieva N.R., Usmonov A.A., Fayzullaev O.A., Tuksanov E.A., Shamsieva N.R.

“V.Vohidov nomidagi Respublika ixtisoslashtirilgan xirurgiya ilmiy-amaliy tibbiyot markazi” davlat muassasasi

Abstrakt

Maqsad. Jigar paneli parametrlarini, subklinik yallig'lanish belgilarini, gemostazni va tirik jigar donorlarida endotelial disfunktsiyani donor hemihepatektomiyadan keyingi kechki davrda baholash.

Materiallar va usullar. Tadqiqotga 131 ta jigar lob donorlari kiritilgan. Ulardan 120 donor operatsiyadan oldin va donorlikdan keyin 12, 24 va 36 oy ichida kuzatuv bilan bitta markazda operatsiya qilindi. Chet elda operatsiya qilingan qo'shimcha 11 donor donorlikdan 12–96 oy o'tgach tekshirildi. Laboratoriya tekshiruvlariga to'liq qon ro'yxati, jigar va asosiy metabolik panel qiymatlari, koagulyatsion profil va yallig'lanish belgilari (C-reaktiv oqsil, interleykin-6) va endotelial disfunktsiya (von Villebrand omili, homosistein) kiradi. Statistik tahlil MedCalc v23.0.8 yordamida amalga oshirildi.

Natijalar. Metabolik profilning asosiy parametrlari, gemoglobin darajasi, trombotsitlar soni va koagulyatsion skrining testlari mos yozuvlar oralig'ida qoldi. Donorlikdan 12 oy o'tgach, leykotsitlar va limfotsitlar sonining sezilarli o'sishi kuzatildi ($p < 0,05$). Subklinik yallig'lanish belgilari (IL-6, CRP, fibrinogen) 24 va 36 oylarda asta-sekin o'sib boradi. Xolestazning laboratoriya belgilari - umumiy va to'g'ridan-to'g'ri bilirubin va gidroksidi fosfataza faolligi oshishi - 24 oydan boshlab aniqlangan. Endotelial disfunktsiya belgilari 12 oylik kuzatuvdan barqaror o'sishni ko'rsatdi.

Xulosa: Jigar donorligidan keyingi kech davrda donorlarda boshlang'ich laboratoriya ko'rsatkichlarini saqlab qolgan holda subklinik yallig'lanish, endotelial disfunktsiya va progressiv xolestaz belgilari rivojlanadi, bu uzoq muddatli maqsadli monitoring zarurligini asoslaydi.

Kalit so'zlar: tirik jigar donatsiyasi, hemigeptektomiya, subklinik yallig'lanish, endotelial disfunktsiya, xolestaz.

Relevance of the problem. Living donor liver transplantation (LDLT) remains a crucial strategy for expanding the donor pool and saving patients with end-stage liver disease, particularly those with decompensated cirrhosis [2,5]. In the context of living donation, the procedure is performed on a healthy individual; therefore, donor safety is the highest priority in clinical practice, and the donor themself represents the central figure in living liver transplantation [1,2,3,4,11]. With appropriate selection and follow-up, living liver donation is safe, with mortality rates below 0.5% and considered an exceptional event. According to aggregated literature, donor mortality ranges from 0.04–0.2%, and in large pooled cohorts it is even lower — approximately 0.06%, i.e., roughly one death per several thousand donors [1,5].According to various authors, overall surgical complications of Clavien–Dindo grade > II occur in 20–30% of liver donors, while major complications (Clavien–Dindo grades III–IV) do not exceed 5–10% [10]. As a rule, donors maintain normal liver function (ALT, AST, bilirubin), demonstrate complete or near-complete liver volume regeneration, and preserve normal long-term survival [4,11]. Clinical studies with CT/MRI volumetric assessment demonstrate a characteristic pattern of remnant liver regeneration: within 1–4 weeks, the residual parenchyma typically reaches approximately 65–80% of the original liver volume; by 3–6 months, the volume more often attains 80–90%; and by 12 months, most donors reach 85–95% (reported ranges in different series: 83–91% at 12 months) [4,6].In the long-term postoperative period, the most common complaint among donors is discomfort at the surgical site (13.2–38.8%), followed by psychological disorders (1–22%). Biliary strictures develop with a frequency of 1–14% [5], while overall quality of life generally remains unaffected [1,2]. Markers of hepatocellular injury (cytolysis), cholestasis, and inflammation usually normalize by the end of the second postoperative week [9]. However, complete morphological and functional recovery may take up to one year, as regeneration depends on the extent of hepatic resection (right vs. left lobe), donor age, degree of hepatic steatosis, and other concomitant factors [3]. Our previous findings demonstrated that hemihepatectomy in living-related liver donors is associated with only mild manifestations of cytolysis and cholestasis, which resolve within the first postoperative week. A characteristic feature of the inflammatory response following donor hemihepatectomy is a peak in the pro-inflammatory mediator IL-6 at 12 hours, and a peak in the inflammatory effector CRP at 24 hours, with normalization occurring by days 5–10, and without any evidence of endothelial dysfunction [8,9].

Thus, the liver demonstrates a high reparative capacity, and in donors it fully compensates for the loss of a hepatic lobe within 6–12 months. Donor complications (including bleeding, biliary leaks and strictures, cholelithiasis, portal vein thrombosis,

infections, and in some cases psycho-emotional disorders) occur in 0–30% of cases. The heterogeneity of published data is largely attributable to variations in sample sizes and the limited degree of investigation of this issue. Most donor-focused studies concentrate on the first 6–12 months after surgery, when regenerative processes are most active and acute events may still occur. For long-term prognostication of liver status after donation, it is essential to assess subclinical inflammation and its biomarkers — high-sensitivity CRP, IL-6, TNF-α — as these are also indicators of cardiovascular risk, fibrosis, and oncologic potential.

The objective of the study was to evaluate the biochemical indices of hepatic function and the circulating biomarkers of subclinical inflammation in living liver donors during the long-term postoperative period following donor hemihepatectomy.

Material and Methods. A total of 131 living-related liver donors were included in the study. Among them, 120 donors underwent hemihepatectomy at the Republican Specialized Scientific-Practical Medical Center of Surgery named after Acad. V. Vakhidov between August 2022 and August 2025. Their follow-up included comprehensive clinical and laboratory assessment in the early postoperative period, as well as at 12, 24, and 36 months after donation. In addition, as part of a screening initiative launched by the Center's administration, 11 donors who had undergone donation surgery in various clinics in India and Turkey were examined; the interval since donation in this subgroup ranged from 12 to 96 months. All donors underwent assessment of the basic metabolic panel, hepatic biochemical profile, and lactate levels using a fully automated VITROS-5600 biochemical analyzer (USA) with standardized reagent kits from the same manufacturer (closed analytical system, all methods validated by the manufacturer), under stable operation of the internal quality-control system. Hemostatic parameters were evaluated on an automated ACL-TOP 350 coagulometer using standardized reagent kits from Instrumentation Laboratory (Werfen, USA). The methods included routine coagulation screening tests—activated partial thromboplastin time (aPTT), prothrombin time (PT), international normalized ratio (INR), fibrinogen (Fbg)—as well as specialized assays including antithrombin III (AT-III), protein C, protein S, and plasminogen; all analytical procedures were validated by the reagent manufacturer. Hematologic analysis was performed on an automated DxH-500 hematology analyzer (Beckman Coulter, USA), with determination of 23 parameters, including hemoglobin (Hb), total leukocyte count (WBC), platelet count (PLT), and lymphocytes (Lymph). Markers of inflammation, including CRP and IL-6, were quantified using an mmunofluorescence analyzer FIA METER PLUS FS-205 (Wondfo, China) with corresponding test cartridges from the same manufacturer. All laboratory analyses were performed under stable operation of the internal quality-control system. Digital data were processed statistically using

MedCalc (version 23.0.8, 2024). Results are presented as mean (M) and standard deviation (σ), expressed as M ± σ. For inferential statistics, the t-test for independent samples was employed, and differences were considered statistically significant at $p < 0.05$ for all analytical methods.

Results. A total of 131 donors were examined, including 78 men (59.5%) and 53 women (40.5%). The distribution of donors according to the timing of follow-up assessments is presented in Table 1 (Tab. 1).

Table 1

Distribution of donors according to follow-up intervals

Follow-up interval	Before donation	6 month	12 month	24 month	36 month	48 month	More than 48 month
Number of donors, n	120	99	83	44	10	2	2

The mean age of donors at the time of preoperative baseline evaluation was 32.6 ± 8.3 years, and the mean body mass index (BMI) was 22.1 ± 1.95 kg/m². All donors met the eligibility criteria for living-related liver donation. Assessment of linear and volumetric hepatic parameters based on contrast-enhanced MSCT demonstrated that the total liver volume was 1308.4 ± 243.7 mL, while the graft weight procured from the donor averaged 692.7 ± 139.1 g. In the baseline metabolic status, donors demonstrated no deviations of laboratory parameters from the reference interval. At the 6-month follow-up, none of the donors exhibited any elevation or reduction of the assessed laboratory indicators beyond reference limits. Basic hematologic parameters remained within physiological reference ranges at all follow-up points. However, subthreshold fluctuations were observed in WBC and lymphocyte counts, whereas hemoglobin concentration and platelet counts did not show statistically significant changes relative to the time elapsed since donation. Thus, hemoglobin levels remained within 112–140 g/L throughout the observation period. The WBC count increased significantly by 1.3-fold and 1.2-fold relative to baseline at 12 and 24 months after hemihepatectomy, respectively ($p < 0.05$). The absolute lymphocyte count increased 1.4-fold from baseline at 12 months ($p < 0.05$) and remained at this elevated level at 24 and 36 months of follow-up. Notably, the relative lymphocyte fraction increased from 29.4% at baseline to 40.3% at 36 months post-donation ($p < 0.05$) (Table 2).

Table 2

Hematological parameters in the long-term period after liver donation

Parameter	Unit of measurement	Reference interval	Before donation	12 month After donation	24 month After donation	36 month After donation
Hb	g/l	120-140, 130-160	124,6±7,6	112±4,9	133±5,7	129,6±7,9
WBC	10^9/l	4,0-9,0	5,94±0,61	7,56 ±1,01*	7,23± 1,23*	7,2±1,1*
Lymph (abs)	10^9/l	0,8-4,0	1,92±0,33	2,69 ±0,45*	2,85 ±0,52*	2,74±0,23*
Lymph, %	%	19-39	29,4±0,6	31,8±3,6	34,5±2,2*	40,3±2,1*^
PLT	10^9/l	150-420	230±23	236±39	253±32	259±43

*- *statistically significant relative to the pre-donation value*

^- *statistically significant relative to the 12-month post-donation value*

These findings warrant further in-depth investigation within the framework of an expanded immunological profile in donors during the long-term postoperative period.

The assessment of basic metabolic and hepatic panel parameters demonstrated the absence of cytolysis at all points during the 3-year follow-up period. In contrast, biochemical signs of cholestasis showed a progressive increase over time in liver donors. A trend toward elevated alkaline phosphatase activity and an increase in total bilirubin, predominantly due to the direct fraction, was observed. Alterations in hepatic panel parameters began to appear 24 months after donation, with a corresponding increase in the number of donors exhibiting a cholestatic profile:

– at 12 months, cholestasis was observed in 1.2% of donors (1 of 83);

– at 24 months, in 6.8% (3 of 44);

– at 36 months, in 40% (4 of 10) (Table 3).

Levels of total protein, albumin, glucose, electrolytes, urea, creatinine, and lactate did not differ statistically from baseline at any stage of the study.

The evaluation of routine coagulation screening tests revealed no abnormalities at any follow-up point. In contrast, specialized coagulation assays demonstrated greater variability after liver donation. A trend toward increased plasminogen activity was observed, along with a significant rise in fibrinogen levels, which exhibited a time-

dependent progression: a 1.3-fold and 1.4-fold increase compared with baseline at 24 and 36 months, respectively ($p < 0.05$).

Table 3

Results of hepatic and basic metabolic panel testing in the long-term period after liver donation

Parameter	Unit of measurement	Reference interval	Before donation, p1	12 month After donation p2	24 month After donation p3	36 month After donation p4
ALT	U/L	15-45	22,8±3,5	28,9±9,3	22,3± 5,8	25,6±7,4
AST	U/L	11-66	24,5±3,9	15,8±8,5	21,2±4,6	22,5±6,9
Total bilirubin	µmol/L	1,7-17,5	13,2±6,5	13,9±9,7	15,2± 6,4	36,8±7,3*^
Direct bilirubin	µmol/L	0-5	0,5±0,1	4,5±0,4*	4,6±0,4*^	6,8±2,5*^
ALP	U/L	38-126	63,0 ±15,0	68,0±13,7	71,7±9,3	82,0±11,0
Lactate	mmol/L	1,3-3,3	1,76±0,2	1,8±0,3	1,9±0,2	1,9±0,5
Glucose	mmol/L	3,3-6,0	4,91± 0,41	5,02±0,35	4,81 ±0,12	4,32±0,22
Total protein	g/L	64-83	78,1±3,2	74,4±2,7	73,6±2,1	74,2±2,6
Albumin	g/L	32-52	46,0± 2,0	44,4±2,5	43,9±1,9	44,1±1,9
Globulins	g/L	26-47	32,1±1,3	30,5±1,3	30,8±1,1	31,0±1,3
Urea	µmol/L	2,1-7,1	5,75±0,9	4,63±1,5	6,1±1,0	4,8±1,2
Creatinine	µmol/L	70–110 (m),55–95 (w)	64,0±8,5	65,3±10,5	68,3±9,6	78,6 ±13,4
Sodium	mmol/L	136-145	138,1±1,8	137,5±1,4	137,7± 0,6	137,2± 0,4

Potassium	mmol/L	3,5-5,1	4,0±0,3	4,1±0,1	4,1±0,1	4,2±0,2

**- statistically significant relative to the pre-donation value*

^- statistically significant relative to the 12-month post-donation value

Given that fibrinogen functions not only as a component of the hemostatic system but also as a pro-inflammatory acute-phase protein, its elevation serves as a signal for heightened vigilance regarding thrombotic and inflammatory complications in living liver donors. Although donors appeared relatively healthy on routine clinical and laboratory assessment, in-depth evaluation revealed a less reassuring profile, indicating that subtle but clinically relevant deviations may manifest during long-term follow-up after living liver donation. Assessment of inflammatory syndrome parameters demonstrated a statistically significant increase in IL-6 concentrations (by 2.9-fold and 6-fold relative to baseline at 24 and 36 months, respectively; $p < 0.05$) and in CRP levels (by 2.0-fold and 2.2-fold at 24 and 36 months; $p < 0.05$) during long-term follow-up after hemihepatectomy. Notably, both biomarkers exceeded their respective reference intervals at 24- and 36-months post-donation. A significant elevation of fibrinogen relative to baseline at the same time points provides additional evidence of persistent subclinical inflammation in living liver donors during the remote postoperative period. A potential association between chronic low-grade inflammation and endothelial dysfunction (ED) should also be considered, as laboratory indicators of ED were detected 12 months after donation, manifested by increased von Willebrand factor (vWF) activity and antigen levels, with a progressive rise in vWF activity observed against a background of persistently elevated vWF antigen. Additionally, a statistically significant increase in homocysteine levels was observed. Although these values remained within reference limits, they can be considered another indirect indicator of impaired endothelial homeostasis (Table 4).

Table 3

Results of Hemostasiogram Parameters and Inflammatory Markers in the Long-Term Period After Living Liver Donation

Parameter	Unit of measurement	Reference interval	Before donation, p1	12 month After donation p2	24 month After donation	Parameter
IL-6	pg/mL	0-10	4,31±1,4	3,56±0,56	12,4±4,5*^	26,8±8,9*^

CRP	mg/L	0-5	3,0±1,0	5,76±2,1*	5,99 ±1,7*	6,4±1,5*
Fibrinogen	mg/dL	276-471	339,5± 45,0	393,0± 80,5	441,0± 56,0*	467,0±67,1 *
Homocysteine	mmol/L	4,1-11,1	6,96±1,0	7,6±1,1	8,8±0,9 *	9,4±1,7*^
von Willebrand factor (Ag)	%	66-176	98,5 ±10,3	137,5± 11,2*	144,3± 12,3*	146,4±13,4 *
von Willebrand factor (act)	%	48-201	97,3±9,8	145,6± 12,4*	199,8 ±15,6*^	242,4±6,5* ^
Plasminogen	%	80-132	96,2±14,9	110,6± 21,0	125,1± 18,5	132,0±23,0
Antithrombin III	%	83-128	100,3± 8,5	95,0±10,8	104,6± 6,9	113,0±12,8
APTT	s	24-43	32,5±2,3	32,6±3,4	35,4 ±1,4	35,9±2,0
PT	s	12-16	11,9±0,5	11,4±0,8	10,6± 0,6	11,4±0,4
INR	E	0,7-1,3	1,10±0,04	0,98±0,02	0,91 ±0,06	0,99±0,03
Protein C	%	70-140	84,6±11,0	88,8±12,0	79,5 ±23,4	83,8±12,0
Protein S	%	54,7-146	83,4±12,0	90,6±17,0	94,6 ±13,9	98,0±23,9

** — statistically significant compared with the pre-donation baseline*
^ — statistically significant compared with the 12-month post-donation value

Thus, in the long-term period after living liver donation, the following alterations in liver panel parameters were observed: an increase in total and direct bilirubin and alkaline phosphatase, indicating the gradual development of a cholestatic syndrome; an increase in total leukocyte count, IL-6, CRP, and fibrinogen, reflecting the progression of chronic subclinical inflammation; and elevated von Willebrand factor

activity and homocysteine levels, which represent laboratory markers of endothelial dysfunction.

Subclinical inflammation represents a chronic, low-grade inflammatory state that does not manifest with overt clinical symptoms but is detectable through laboratory biomarkers (CRP, IL-6, TNF-α, oxidative stress markers, endothelial dysfunction indicators) and/or histological or morphological changes (e.g., cellular infiltration, increased expression of pro- and anti-inflammatory cytokines within the tissue). In the context of living liver donation, this form of inflammation may persist or develop after hepatic volume restoration, despite the absence of clinical manifestations and typically normal liver biochemistry results [3,7]. It is known that donors with pre-existing hepatic steatosis often demonstrate slower recovery kinetics, and alterations in lipid metabolism and insulin resistance may contribute to persistent subclinical inflammation [7]. Some studies have reported slight increases in metabolic syndrome markers (glucose, triglycerides, total cholesterol, LDL) after donation, although no such changes were identified in our cohort [2,7]. Several mechanisms may underlie the development of subclinical inflammation in living liver donors. These include intensified regenerative activity and the activation of signaling pathways and immune cell populations, leading to increased cytokine production and cross-activation of inflammatory protein synthesis [12]. Another key mechanism is ischemia–reperfusion injury, which, through oxidative stress and reactive oxygen species, may trigger NF-κB activation and downstream inflammatory cascades, as well as induce endothelial cell activation and cholangiocyte apoptosis. Our findings support these mechanisms: the observed increase in total lymphocyte percentage indicates activation of immune cell populations, resulting in enhanced production of inflammatory cytokines—followed, in turn, by the elevation of acute-phase reactants such as CRP and fibrinogen. The development of a cholestatic syndrome may be associated with chronic oxygen deficiency within hepatic tissue. By 24 months postoperatively, such hypoxic stress may lead to maladaptive responses and cholangiocyte apoptosis, contributing to the formation of biliary strictures and cholestasis, consistent with the observed elevations of total and direct bilirubin and alkaline phosphatase. Endothelial dysfunction appears to be a central pathological component in this context. It creates a self-reinforcing loop with inflammation, promoting thrombotic complications and microthrombosis, which further exacerbates hepatic ischemia and tissue hypoxia. Incomplete parenchymal regeneration, microinjuries, and subclinical infections—clinically silent but immunologically relevant—may support ongoing low-grade inflammation. This hypothesis, however, warrants further investigation.

The literature also reports that several factors predispose individuals to the progression of subclinical inflammation, including hepatic steatosis, overweight and

obesity, metabolic syndrome, smoking, and an unhealthy lifestyle. The presence of subclinical inflammation carries the risk of several adverse outcomes: diminished hepatic resistance to injurious stimuli, development of cholangitis and biliary cirrhosis, as well as metabolic disturbances such as insulin resistance and dyslipidemia. These abnormalities, in turn, contribute to an increased risk of cardiovascular disease and impaired quality of life and overall health in liver donors. According to Darwish Murad (2016), platelet counts demonstrated a significant reduction to 198×10^9/L compared with 224×10^9/L in the pre-donation control group ($P < 0.001$), although 93% of donors remained within the normal platelet reference range. Imaging studies (MRI and MDCT) revealed no evidence of biliary structural abnormalities or other morphological lesions, and hepatic regeneration was complete [4]. More recent studies, based on liver biopsy findings in donors undergoing LDLT, have provided different insights. Serological testing in these donors did not reveal any pathological changes; however, biopsy results demonstrated hepatic steatosis in 30% of cases, hemosiderosis in 10–20%, biliary abnormalities and neo-duct formation in 16%, fibrosis in 20%, inflammation in 25%, and portal vein dilatation in 50% of cases [3].

Conclusions

1. Living liver donors exhibit no abnormalities in hemoglobin levels, platelet counts, glucose, electrolytes, protein metabolism parameters, or screening coagulation tests throughout the 36-month follow-up period after donation.

2. In the long-term period after liver donation, there are clear indicators of subclinical inflammation and immune system activation, as evidenced by: a statistically significant increase in WBC by 1.3-fold and 1.2-fold relative to baseline at 12 and 24 months, respectively; an increase in lymphocyte count by 1.4-fold compared with baseline during the 12–36-month interval; an increase in the relative proportion of total lymphocytes from 29.4% at baseline to 40.3% at 36 months; elevated IL-6 levels by 2.9-fold and 6-fold relative to baseline at 24 and 36 months, respectively; an increase in CRP levels by 2.0-fold and 2.2-fold relative to baseline at 24 and 36 months. These findings collectively indicate the development of a persistent low-grade inflammatory state in living liver donors during long-term follow-up.

3. In the long-term period after liver donation, there are clear indicators of endothelial dysfunction, which develops by 12 months and persists through 36 months post-donation. This is evidenced by a statistically significant increase in von Willebrand factor activity relative to baseline, as well as a progressive rise in fibrinogen levels—1.3-fold and 1.4-fold above baseline at 24 and 36 months, respectively ($p<0.05$).

4. At 24 months after liver donation, living donors begin to demonstrate laboratory indicators of jaundice and cholestasis. This is reflected by a tendency toward

increased alkaline phosphatase activity and a rise in total bilirubin concentration due to an elevation in the direct fraction. The proportion of donors exhibiting laboratory signs of jaundice and cholestasis was 1.2% (1 of 83) at 12 months, 6.8% (3 of 44) at 24 months, and 40% (4 of 10) at 36 months post-donation.

5. In the long-term period after liver donation, there is an increasing proportion of individuals exhibiting signs of subthreshold hyperhomocysteinemia and elevated von Willebrand factor activity in combination with subclinical low-grade inflammation. These findings highlight the need for therapeutic and preventive measures in living related liver donors.

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АНТРОПОМЕТРИЧЕСКИЕ И ФУНКЦИОНАЛЬНЫЕ ОСОБЕННОСТИ СПОРТСМЕНОВ ПОДРОСТКОВОГО ВОЗРАСТА В ЗАВИСИМОСТИ ОТ СПЕЦИФИКИ СПОРТИВНОЙ ДЕЯТЕЛЬНОСТИ

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