Original Article

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Early post-reperfusion neutrophil dynamics after liver transplantation: Association with graft size

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SUMMARY: Patients with end-stage liver disease often exhibit impaired neutrophil function and have an elevated risk for perioperative infections. Liver transplantation (LT) restores hepatic function; however, perioperative neutrophil dynamics and their association with graft size remain unclear. We retrospectively analyzed 71 adult patients who underwent LT between January 2019 and June 2021. Leukocyte, neutrophil, and lymphocyte counts and the neutrophil-to-lymphocyte ratio were assessed at three intraoperative time points: beginning of surgery (BS), anhepatic phase (AP), and abdominal closure (AC), as well as on postoperative days (PODs) 1–3. The patients were stratified by graft-to-recipient weight ratio (GRWR < 1.0 *vs.* ≥ 1.0), and the correlations between GRWR and leukocyte parameters were evaluated. Neutrophil and leukocyte counts remained unchanged from the BS to AP and increased significantly after graft reperfusion (AC *vs.* BS: $p < 0.01$). Lymphocyte counts declined significantly during surgery. On POD 1, both neutrophil counts and their increases from BS correlated significantly with GRWR in the GRWR < 1.0 group ($r_s = 0.424$ and 0.442, respectively; both $p < 0.01$), although not in the GRWR ≥ 1.0 group. No postoperative infections were observed within 7 days. Graft reperfusion was associated with a robust increase in peripheral neutrophil counts, particularly in the recipients of smaller grafts. These findings suggest an association between graft size and early postoperative neutrophil dynamics, which may help interpret early immune responses after LT.

Keywords: end-stage liver disease, leukocyte kinetics, neutrophil mobilization, graft-to-recipient weight ratio, perioperative immunity

1. Introduction

Liver transplantation (LT) is a definitive and life-saving treatment for patients with end-stage liver disease (ESLD). However, ESLD is associated with profound alterations in host immunity, including quantitatively and qualitatively impaired neutrophil function, which increases the risk for perioperative infections (*1-3*). Understanding perioperative innate immune dynamics is clinically important for managing patients who undergo liver transplantation.

Neutrophils are critical first responders in innate immunity. In ESLD, circulating neutrophil counts are often reduced due to enhanced apoptosis and splenic sequestration (*4,5*). Their perioperative mobilization from bone marrow into peripheral circulation is influenced by inflammatory mediators, surgical stress, and organ function (*6–9*). Notably, clinical observations suggest that neutrophil counts frequently increase after graft reperfusion during LT. Whether the transplanted liver contributes to the modulation of systemic neutrophil mobilization is unclear. The mechanisms underlying perioperative neutrophil mobilization in LT remain poorly understood. Only limited studies have quantified intraoperative changes in circulating neutrophil counts at defined surgical phases. Furthermore, whether the magnitude of neutrophil mobilization varies with graft size, which is an important determinant of early graft performance, is undetermined.

In this retrospective cohort study, we evaluated perioperative changes in leukocyte and neutrophil counts in LT recipients and examined their associations with graft-to-recipient weight ratio (GRWR), a clinically relevant index of graft volume. We hypothesized that neutrophil mobilization would remain attenuated until graft reperfusion and increase thereafter, and that graft size would influence the magnitude of this response. By clarifying the relationship between graft size and early innate immune dynamics, we aimed to provide clinical insight into graft-size-dependent modulation of early innate immune responses following LT.

2. Materials and Methods

2.1. Study design and ethical approval

This retrospective cohort study was approved by the Clinical Research Ethics Committee of the University of Tokyo (approval No. 2203-(7)). The requirement for individual written informed consent was waived due to the observational nature of the study; however, eligible patients were given the opportunity to opt out *via* public notification. The study adhered to the principles of the Declaration of Helsinki and followed institutional policies for patient data protection.

2.2. Patient selection

We identified all adult recipients of liver transplants from either living or brain-dead donors, between January 1, 2019 and June 30, 2021, using the institutional electronic anesthesia record system.

The exclusion criteria comprised preoperative use of immunosuppressive therapy such as for autoimmune disease or re-transplantation; ABO-incompatible LT; fulminant liver failure within 8 weeks of onset; preoperative sepsis or other infection-associated conditions; missing key laboratory data; and patient refusal *via* the opt-out process.

2.3. Anesthetic and perioperative management

All patients underwent general anesthesia with tracheal intubation and mechanical ventilation. The anesthetic technique was at the discretion of the attending anesthesiologist, and volatile-based general anesthesia was used in 69 patients (97.1%).

Perioperative management included:

- Intraoperative circulatory management: dopamine, dobutamine, norepinephrine, or phenylephrine were administered intraoperatively as needed.
- Steroid therapy: intravenous methylprednisolone (20 mg/kg) was administered at the time of patient transfer to the operating room and at graft reperfusion.
- Other intraoperative medications: nafamostat mesilate (1 mg/kg/h) and alprostadil alfadex (0.01 µg/kg/min) were routinely infused from the beginning of surgery.
- Postoperative immunosuppression: all patients received tacrolimus and corticosteroids based on a standardized protocol.

2.4. Graft selection, surgical procedure, and perioperative immunosuppressive regimen

Graft selection for living-donor liver transplantation (LDLT) procedures at our center has traditionally been based on the recipient's standard liver volume (SLV), with a minimum requirement of 35% of the estimated SLV to ensure sufficient functional graft mass, which is consistent with previously reported requirements (*10*). SLV-based criteria are used in a limited number of centers in Japan, and GRWR is the gold-standard index for assessing graft size in LDLT. In this study, GRWR was calculated using the actual graft weight measured at the time of preservation with University of Wisconsin solution and was used for all analyses regarding the impact of graft size. The surgical procedures, including live donor hepatectomy and graft implantation, adhered to standard institutional protocols for LT. The University of Wisconsin solution was used for cold static storage of the liver graft.

The immunosuppressive regimen comprised tacrolimus and methylprednisolone, with gradually tapered doses. The targeted tacrolimus trough level was increased to > 10 ng/mL within 5 days. Methylprednisolone (20 mg/kg) was administered before surgery and during the AP and then tapered to maintenance doses of 3–0.75 mg/kg during the first week after LDLT. Additionally, mycophenolate mofetil was administered to patients with acute or chronic kidney injury.

2.5. Data collection

Demographic and clinical variables were obtained from electronic medical and anesthesia records including age, sex, height, weight, underlying liver disease, Model for End-Stage Liver Disease score, and Child–Turcotte–Pugh score. Graft characteristics such as graft type and GRWR were also recorded. Laboratory data included leukocyte, neutrophil, and lymphocyte counts measured at the beginning of surgery (BS), at AP, after graft reperfusion, at the time of abdominal closure (AC), and at postoperative days (PODs) 1–3. Intraoperative information including anesthetic technique, surgical duration, blood loss, and transfusion volume (red blood cells, fresh frozen plasma, and platelet concentrate), and the intraoperative administrations of steroids, catecholamines, and other continuously infused medications were collected.

This perioperative window (BS–POD 3) was selected to capture innate immune responses expected to peak within 72 hours. In addition to leukocyte subsets, the neutrophil-to-lymphocyte ratio (NLR) was calculated as a composite index reflecting the balance between neutrophil mobilization and lymphocyte depletion, which has been reported as a clinically relevant marker of systemic inflammation in surgical and transplant settings (*11*).

2.6. Outcomes

The primary outcome was the change in leukocyte, neutrophil, and lymphocyte counts as well as the NLR across the perioperative period: BS, AP, AC, and POD 1–3.

The secondary outcomes were the correlations between GRWR and leukocyte or neutrophil counts on POD 1, as well as the correlations between GRWR and the perioperative increase in leukocyte or neutrophil counts from BS to POD 1.

The clinical outcomes, including infection and biopsy-proven acute rejection, were also monitored through POD 7 to document early complications. These outcomes were collected for descriptive purposes and not included in the leukocyte dynamics analysis. To evaluate the effect of graft size, patients were stratified into two groups: GRWR < 1.0 (small-for-size grafts) and GRWR ≥ 1.0.

2.7. Statistical analyses

Categorical variables are presented as absolute counts and percentages. Continuous variables are summarized as mean ± standard deviation or median with interquartile range (IQR), depending on normality assessed by histograms and quantile–quantile plots. Intraoperative changes across timepoints were analyzed using Friedman's test, with Bonferroni correction applied for multiple post hoc comparisons.

Associations between GRWR and leukocyte or neutrophil counts on POD 1, as well as their increases from BS to POD 1, were assessed using Spearman's rank correlation, with analyses conducted separately for GRWR < 1.0 and GRWR ≥ 1.0 groups. A two-sided p value < 0.05 was considered significant.

All statistical analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA). A post hoc power analysis for Friedman's test was additionally conducted using G*Power version 3.1.9.7 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany).

3. Results

3.1. Patient enrollment and baseline characteristics

Between January 1, 2019, and June 30, 2021, a total of 26,780 surgical cases were recorded at our institution. Among them, 117 patients underwent LT. After excluding patients who received preoperative immunosuppressive therapy (*n* = 30), had fulminant hepatic failure within 8 weeks of onset (*n* = 15), or had missing laboratory data (*n* = 1), the remaining 71 patients (60 living-donor LT and 11 deceased-donor LT) were included in the final analyses (Figure 1).

Table 1 presents a summary of patient baseline characteristics. The mean patient age was 50.5 ± 11.3 years, and 54% of patients were men. The mean Model for End-Stage Liver Disease score was 17.1 ± 8.3, and the mean Child–Turcotte–Pugh score was 10.3 ± 2.3. Etiologies of ESLD included viral hepatitis (*n* = 12), alcoholic liver disease (*n* = 14), nonalcoholic steatohepatitis (*n* = 10), cholestatic liver disease (*n* = 19), metabolic liver disease (*n* = 6), vascular disorders (*n* = 6), and other causes (*n* = 4). Graft types included whole liver (*n* = 11), right lobe (*n* = 30), left lobe (*n* = 24), and right posterior segment (*n* = 6).

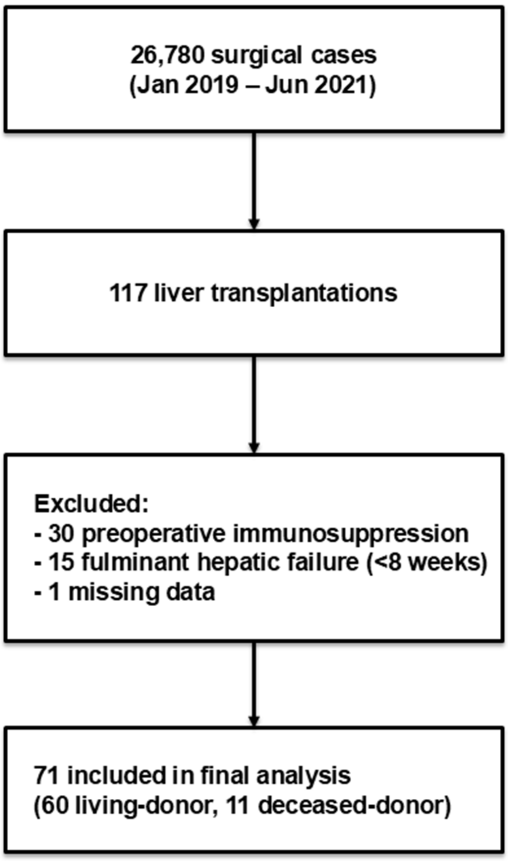

Figure 1. Flow diagram of patient enrollment.

Table 1. Patient characteristics

Factor	
Age (years)	50.5 ± 11.3
Sex (male)	39 (53.9%)
BMI (kg/m^2)	23.6 ± 4.7
MELD score	17.1 ± 8.3
CTP score	10.3 ± 2.3
Indication	
Viral hepatitis	12
Alcoholic liver disease	14
Nonalcoholic steatohepatitis	10
Cholestatic liver disease	19
Metabolic liver disease	6
Vascular disorders	6
Others	4
Graft	
Whole liver/right lobe/left lobe/posterior segment	11/30/24/6

Values are presented as the mean (± standard deviation) or median (interquartile) for continuous variables and *n* (%) for categorical variables. BMI, body mass index; MELD score, model for End-Stage Liver Disease score; CTP score, Child–Turcotte–Pugh score.

3.2. Intraoperative and postoperative course

The intraoperative and postoperative variables are summarized in Table 2. All the patients underwent general anesthesia with endotracheal intubation and mechanical ventilation. Inhalation-based anesthetic techniques were used in 69 patients (97.1%). The mean anesthesia time was 749 ± 79 minutes, and the mean surgical duration was 635 ± 78 minutes. The time from BS to AP was 209 ± 59 minutes and from AP to AC was 344 ± 70 minutes.

Median intraoperative blood loss was 5,135 mL (IQR 3100–9830). Median transfusion volumes were 1,680 mL red blood cells (IQR: 1,120–3,640), 2,640 mL fresh frozen plasma (IQR: 1,440–4,080), and 400 mL platelet concentrate (IQR: 0–600). Intraoperative vasoactive agents (dopamine, dobutamine, norepinephrine, or phenylephrine) were administered as required. Methylprednisolone (20 mg/kg) was administered preoperatively and during reperfusion in all patients. Continuous intraoperative infusions of nafamostat mesilate (1 mg/kg/hour) and alprostadil alfadex (0.01 μg/kg/minutes) were also used routinely.

All patients were admitted to the intensive care unit after surgery with planned mechanical ventilation. The median duration of postoperative mechanical ventilation was 1 day (IQR: 1–1). Three patients required reoperation within 3 days (two for postoperative hemorrhage and one for portal vein thrombosis). These patients were included in the overall leukocyte dynamics analysis. All patients received tacrolimus-based immunosuppression therapy postoperatively. No infectious complications occurred during the 7-day observation period. Six patients (8.5%) experienced biopsy-proven acute rejection after POD 6.

Table 2. Intraoperative and postoperative courses

Factors	
Intraoperative factors	
Anesthesia method (inhalation anesthesia)	69 (97.1%)
Anesthesia time (min)	749 ± 79
Surgical time (min)	635 ± 78
Blood loss (mL)	5,135 (3,100–9,830)
Volume of infusion (mL)	6,100 (4,850–7,802)
Blood transfusion (mL)	4,560 (2,400–8,680)
RBC transfusion (mL)	1,680 (1,120–3,640)
FFP transfusion (mL)	2,640 (1,440–4,080)
PC transfusion (mL)	400 (0–600)
GRWR (%)	0.81 (0.68–1.12)
CIT (min)	99 (77–137)
WIT (min)	35 (31–42)
From BS to AP (min)	209 ± 59
From AP to AC (min)	344 ± 70
Intraoperative steroid use	71 (100%)
Postoperative factors	
Postoperative immunosuppressant use	71 (100%)
Ventilator duration (days)	1 (1–1)
Reoperation within 3 days	3 (4.2%)
Infectious complications within 7 days	0 (0%)
Biopsy-proven acute rejection within 7 days	6 (8.5%)

Values are presented as the mean (± standard deviation) or median (interquartile range) for continuous variables and *n* (%) for categorical variables. RBC, red blood cell; FFP, fresh frozen plasma; PC, platelet concentrate; GRWR, graft-to-recipient weight ratio; CIT, cold ischemic time; WIT, warm ischemic time; BS, beginning of surgery; AP, anhepatic phase; AC, abdominal closure.

3.3. Perioperative leukocyte dynamics

Perioperative changes in leukocyte subsets are shown in Figure 2. Total leukocyte counts remained stable between the BS and AP (median: 3.3 → 3.8 × 10^3/μL; not significant), followed by a significant increase after reperfusion, peaking at AC (7.6 × 10^3/μL). The overall difference across the three intraoperative time points was significant (Friedman test, $p < 0.01$), with post hoc analysis confirming significant increases at AC compared with both BS and AP (both $p < 0.01$). Neutrophil counts demonstrated a similar trend: unchanged between BS and AP (2.4 → 3.1 × 10^3/μL; not significant) and then rising markedly after reperfusion to 6.8 × 10^3/μL at AC (AC *vs.* BS and AP, both $p < 0.01$).

In contrast, lymphocyte counts began to decline during AP ($p = 0.035$) and fell further to 3.2 × 10^2/μL at AC ($p = 0.035$), consistent with perioperative lymphopenia. Consequently, NLR increased significantly from BS (median 5.9) to AP (8.5, $p = 0.045$+) and further to AC (19.6, $p < 0.01$), reflecting the divergence between neutrophil mobilization and lymphocyte depletion.

These findings indicate that the perioperative leukocyte increase was predominantly neutrophil-driven, whereas lymphocytes decreased in parallel.

3.4. Postoperative course: PODs 1–3

As shown in Figure S1 (*https://www.biosciencetrends.com/action/getSupplementalData.php?ID=305*), leukocyte and neutrophil counts increased further on POD 1 compared with those at AC (median leukocyte = 8.1 × 10^3/μL; neutrophils = 7.4 × 10^3/μL). On PODs 2 and 3, both parameters remained elevated at levels similar to those on POD 1 and did not return to baseline, indicating a sustained neutrophil-dominant leukocytosis during the early postoperative period. Contrastingly, lymphocyte counts remained suppressed throughout PODs 1–3. Consequently, NLR also remained elevated across PODs 1–3, reflecting the persistent predominance of neutrophils in the early postoperative phase.

3.5. Correlation with graft size

When the patients were stratified by GRWR, significant associations were observed only in the GRWR < 1.0 group ($n = 49$). In these recipients, both leukocyte and neutrophil counts on POD 1 correlated positively with graft size ($r_S = 0.413$, $p = 0.003$, and $r_S = 0.424$, $p = 0.002$, respectively). Similarly, increases from BS to POD 1 also showed significant correlations ($r_S = 0.444$, $p = 0.001$ for leukocytes; $r_S = 0.442$, $p = 0.001$ for neutrophils). In contrast, among the recipients with GRWR ≥ 1.0 ($n =$

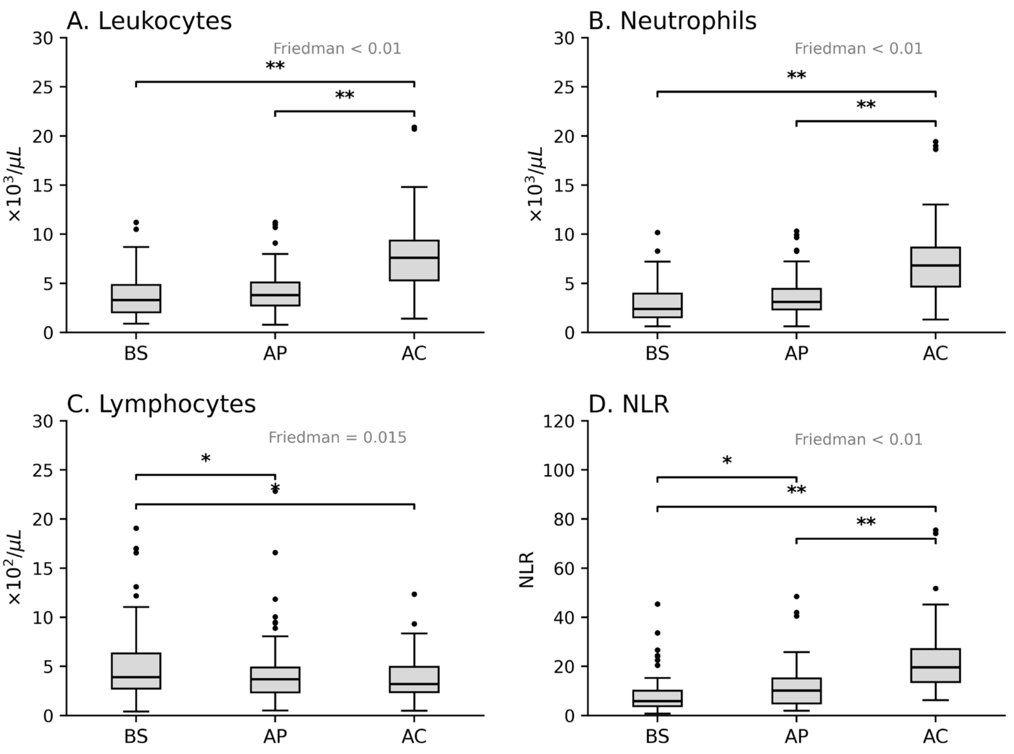

Figure 2. Temporal changes in leukocyte-related parameters. (A), Leukocyte count; **(B)**, neutrophil count; **(C)**, lymphocyte count; and **(D)**, NLR. The Friedman test was used to detect differences across the three intraoperative time points (BS, AP, and AC). Bonferroni-adjusted Wilcoxon signed-rank tests were used for post hoc analysis. Box plots show the median (horizontal line), interquartile range (box), 10–90 percentiles (whiskers), and outliers (dots). *$p < 0.05$, **$p < 0.01$. BS, beginning of surgery; AP, anhepatic phase; AC, abdominal closure; NLR, neutrophil-to-lymphocyte ratio.

21), no significant correlations were observed between graft size and POD 1 leukocyte or neutrophil counts, nor with their perioperative changes.

3.6. Post hoc power

The Friedman's test for neutrophil counts across intraoperative phases (BS–AP–AC) yielded $\chi^2 = 63.7$ (df = 2, $n = 71$); the post hoc analysis showed an effect size w = 0.45 and statistical power of 0.93, supporting the robustness of the primary findings.

4. Discussion

In this retrospective cohort study, we evaluated the perioperative dynamics of leukocyte subsets in patients with ESLD undergoing LT. We found that leukocyte and neutrophil counts remained unchanged from the BS to AP and then increased significantly after graft reperfusion, with maximal values observed at AC. This increase occurred in parallel with a decline in lymphocyte counts. In the recipients with GRWR <1.0, the magnitude of neutrophil increase on POD 1 correlated positively with graft size. These findings suggest graft-dependent modulation of early postoperative neutrophil mobilization.

In most surgical settings, neutrophil counts increase markedly within the first few hours after the start of surgery, usually within approximately 3 hours, driven by cortisol and granulocyte colony-stimulating factor (G-CSF) release (*12–15*). In contrast, neutrophil counts in the present study did not increase during the AP (>3 h after baseline) despite ongoing surgical stress. This pattern may reflect a relatively attenuated mobilization response in ESLD, possibly related to cirrhosis-associated immune alterations.

After reperfusion, leukocyte counts increased sharply, with a marked increase in neutrophils and a decrease in lymphocytes. This pattern may reflect enhanced neutrophil mobilization into the peripheral circulation, although redistribution cannot be excluded. Blood loss differed before and after reperfusion (median 645 *vs.* 497 mL/h); however, the abrupt increase in neutrophil counts immediately after reperfusion suggests that hemodilution alone is unlikely to fully explain this change. The postoperative lymphopenia is consistent with previous reports linking it to surgical stress and immune redistribution (*16–21*). The divergence between neutrophil mobilization and lymphocyte depletion may indicate that these leukocyte subsets are influenced by partially distinct regulatory pathways during LT.

The mobilization of neutrophils in response to surgical injury has been well described (*22–24*), and our findings suggest that this response may be relatively blunted in ESLD and increases substantially after reperfusion. From a mechanistic perspective, neutrophil mobilization during liver transplantation is likely governed by a combination of cytokine-mediated bone marrow release and redistribution within the peripheral circulation. Surgical stress and reperfusion are known to induce rapid increases in circulating G-CSF and interleukin-8 (IL-8), which promote neutrophil release from the bone marrow and enhance chemotaxis (*6,25,26*). In addition, ischemia–reperfusion injury is associated with endothelial activation and increased expression of adhesion molecules, which can alter neutrophil margination and trafficking (*27*). The transplanted liver may contribute to this process as a potential source of inflammatory mediators after reperfusion (*26*), although systemic responses are also likely involved. In recipients with smaller grafts, altered cytokine production or clearance may partly contribute to the observed graft-size–dependent differences in neutrophil dynamics. In the present study, cytokine levels were not measured; however, these mechanisms may partly explain the marked increase in neutrophil counts after reperfusion. Notably, among recipients with a GRWR < 1.0, the magnitude of neutrophil increase up to POD 1 correlated with graft size, whereas no such correlation was observed in those with a GRWR ≥ 1.0. This finding may reflect differences in inflammatory responses in relatively small grafts, potentially related to susceptibility to ischemia–reperfusion injury. However, these interpretations remain speculative and warrant further investigation.

As our center uses SLV-based criteria (SLV ≥ 35%) for graft selection, the generalizability of graft-size–related findings may be questioned. To ensure comparability, all analyses in this study used GRWR based on actual graft weight.

From a perioperative management perspective, these results may be clinically relevant. Volatile anesthetics and perioperative steroids are known to modulate neutrophil and lymphocyte function (*8,13,20,28,29*); however, the absence of intraoperative neutrophil increase until reperfusion suggests that graft-related factors may contribute to perioperative neutrophil dynamics beyond pharmacologic influences. Nafamostat and alprostadil, both administered routinely, may influence inflammatory responses (*30,31*), although their specific contribution in this setting remains unclear. Although NLR increased during the perioperative period, this change primarily reflected neutrophil mobilization rather than an independent immunological process and should therefore be interpreted as a supportive marker rather than a primary indicator.

On POD 1, samples were obtained more than 9 hours after reperfusion. Neutrophils are known to survive longer when recruited locally to inflammatory sites (*27,32,33*); however, their half-life in systemic circulation is estimated to be 6–9 hours (*34,35*). More recent studies have suggested that circulating neutrophils may persist longer under certain conditions (*32,36*). Based on these kinetics, the increase observed on POD 1 is more consistent with mobilization of recipient-derived cells than with donor-derived neutrophils. Perfusion flushes of the graft further reduce the likelihood of donor cell spillover. Although neutrophil accumulation within grafts has been documented (*37–39*), our findings suggest that systemic mobilization may exceed sequestration within the graft when the graft size is adequate.

This study provides clinical insight into perioperative neutrophil dynamics during LT, an area that has not been extensively characterized. In Japan, where living-donor transplantation predominates, graft size varies widely, offering an opportunity to examine the immunologic consequences of limited graft mass. Such insights may be less accessible in regions dominated by deceased-donor transplantation and may therefore offer complementary perspectives on perioperative innate immune dynamics.

The absence of neutrophil mobilization during AP, followed by a marked increase after reperfusion, suggests that graft-related factors after reperfusion may contribute to systemic neutrophil mobilization. Although we did not measure mediators such as G-CSF or IL-8, these mediators may contribute to the observed changes, and future studies incorporating cytokine profiling are warranted. Importantly, all rejection episodes occurred after POD 6, outside the perioperative observation window, suggesting that leukocyte dynamics captured here primarily reflect early innate immune responses rather than alloimmune rejection.

4.1. Limitations

This was a single-center retrospective study and is therefore subject to residual confounding. Perioperative interventions, including corticosteroids, immunosuppressive therapy, blood transfusion, vasoactive agents, and anesthetic management, may have influenced leukocyte dynamics; however, these factors were not formally adjusted for in the present analysis. The relatively small sample size, particularly in the GRWR ≥1.0 group, may have limited statistical power and increased the possibility of false-negative findings. The distribution of GRWR values is shown in Figure S2 (*https://www.biosciencetrends.com/action/getSupplementalData.php?ID=305*). In addition, differences in group sizes may have resulted in differences in baseline characteristics between groups, which could influence the interpretation of the observed associations. Multivariable analysis was not performed due to the limited sample size, and residual confounding cannot be excluded.

Leukocyte dynamics were analyzed only through POD 3 to focus on the perioperative phase, whereas clinical outcomes were monitored through POD 7. The absence of early infections and the low number of events limited the ability to assess associations between neutrophil dynamics and clinical outcomes. Therefore, the prognostic significance of these findings remains uncertain.

Cytokine measurements were not available, which may limit mechanistic interpretation of the observed neutrophil dynamics. Finally, although subgroup analyses based on GRWR were performed, the relatively small number of patients in each group may limit the robustness of these findings.

4.2. Clinical implications

Perioperative neutrophil dynamics, particularly in recipients with small grafts, may provide additional context for interpreting early postoperative immune changes. Routine leukocyte monitoring may complement conventional parameters in anesthetic practice when interpreted alongside clinical findings.

Beyond descriptive interpretation, these findings may inform future approaches to risk assessment. Integration of perioperative neutrophil dynamics with inflammatory mediators, such as cytokine profiles, may facilitate early identification of immune-related complications following LT. Although such applications remain speculative, they warrant further investigation in prospective studies to evaluate their clinical utility.

4.3. Conclusion

In patients with ESLD undergoing LT, neutrophil counts did not increase until after graft reperfusion, at which point they increased markedly. In recipients with small grafts (GRWR < 1.0), the magnitude of this increase was associated with graft size, suggesting graft-size-dependent differences in early postoperative neutrophil dynamics.

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