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Pretransplant Malnutrition and Early Post-Transplant Mortality in Paediatric Liver Transplant Recipients: A Retrospective Cohort Analysis Using Anthropometric Z-Scores

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1. Abstract

1.1. Background

Pretransplant malnutrition is common among paediatric liver transplant candidates and has been associated with adverse postoperative outcomes. However, its independent impact on early post-transplant mortality remains controversial. This study aimed to evaluate the association between anthropometric malnutrition indices and early mortality following paediatric liver transplantation.

1.2. Methods

In this retrospective cohort study, 99 paediatric liver transplant recipients were analysed. Pretransplant nutritional status was assessed using height-for-age (Boy_Z) and weight-for-age (Kilo_Z) Z-scores. Stunting and underweight were defined as Z-score < −2. Early mortality was defined as death within 6 months post-transplant. Patients were also categorized according to postoperative death timing (≤30 days vs >30 days). Logistic regression and Cox proportional hazards models were used to assess independent predictors of mortality, adjusting for age, sex, and disease severity (PELD for <12 years; MELD for ≥12 years).

1.3. Results

Pretransplant stunting and underweight were observed in 32.3% and 35.4% of patients, respectively. Overall mortality was 20.2%, with early mortality (≤6 months) of 16.2%.

In multivariable logistic regression models stratified by age group, disease severity scores (PELD in <12 years) were independently associated with early mortality (OR 1.08 per point increase, p=0.037), whereas anthropometric Z-scores were not.

In Cox proportional hazards analysis for 6-month survival, neither height Z-score (HR 0.98, p=0.94), weight Z-score (HR 1.46, p=0.31), nor ordinal malnutrition severity (HR 1.41, p=0.53) were independently associated with mortality.

However, among patients who died (n=20), those who died after 30 days had significantly lower height Z-scores compared to those who died within 30 days (median −2.64 vs −0.52, p=0.020), suggesting a potential association between chronic stunting and later early-phase mortality.

1.4. Conclusions

In this cohort, pretransplant anthropometric malnutrition

was not independently associated with overall early (≤6 months) mortality after paediatric liver transplantation. Disease severity remained the primary determinant of early mortality risk. However, lower height-for-age Z-scores were associated with deaths occurring beyond the first postoperative month, indicating that chronic malnutrition may influence subacute mortality patterns. Larger multicentre studies are needed to clarify the temporal impact of malnutrition on post-transplant survival.

2. Introduction

Paediatric liver transplantation (LT) is a life-saving therapy for children with end-stage liver disease; however, early post-transplant mortality remains a clinically significant challenge. Despite improvements in surgical technique and perioperative management, risk stratification in paediatric transplant candidates remains imperfect. National registry analyses have demonstrated that young children, particularly those under two years of age, continue to experience substantial waitlist and early post-transplant mortality, underscoring the need to better define modifiable risk factors [1]. Malnutrition is highly prevalent in children with chronic liver disease and results from reduced intake, malabsorption, hypermetabolism, and chronic inflammation [2]. Growth failure is particularly common in cholestatic liver disease and biliary atresia, and has been incorporated into the Paediatric End-Stage Liver Disease (PELD) score as a dichotomous variable [3]. However, the binary threshold approach used in PELD may inadequately capture the continuous burden of anthropometric impairment. Swenson et al. demonstrated that current PELD growth failure thresholds may create a "growth failure gap," potentially underestimating mortality risk in children with substantial but sub-threshold linear growth impairment [3].

Furthermore, limitations in the predictive accuracy of PELD for short-term mortality have been reported. Chang et al. found that PELD systematically underestimated 90-day mortality risk in paediatric transplant candidates, raising concerns regarding risk calibration [4]. Beyond laboratory-based severity scores, functional status has emerged as an independent predictor of both waitlist and post-transplant mortality [5]. Similarly, frailty constructs adapted for paediatric liver disease populations have been shown to identify physiologic vulnerability not captured by traditional clinical indices [6].

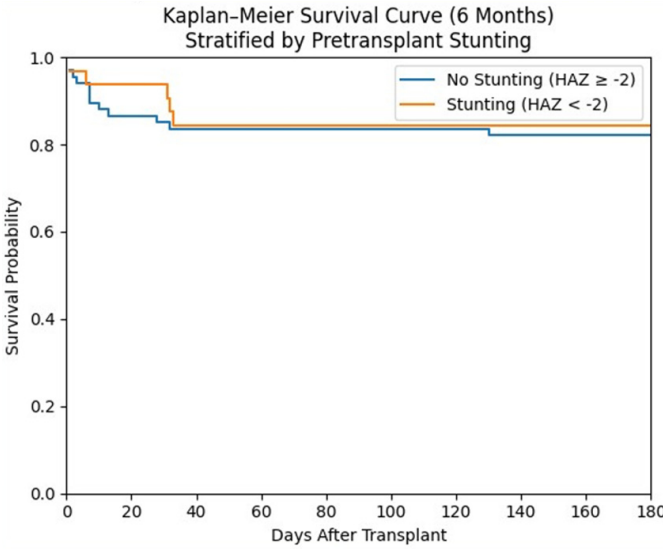
Anthropometric assessment remains widely used in clinical practice because of its accessibility and feasibility. However, weight-based indices may be confounded by ascites and fluid retention in advanced liver disease [7]. In contrast, height-for-age Z-score may better reflect chronic nutritional deprivation and long-term physiologic compromise. Sarcopenia studies in paediatric LT candidates have suggested that muscle mass depletion may be associated with increased mortality, although definitions and measurement techniques remain heterogeneous [7,8].

While malnutrition is biologically plausible as a determinant of postoperative outcomes, its independent association with early post-transplant mortality remains unclear. Some studies suggest that growth failure contributes to adverse outcomes, whereas others indicate that disease severity may overshadow nutritional status in early mortality prediction. Importantly, most prior analyses have evaluated early mortality as a unified endpoint without considering potential time-dependent effects.

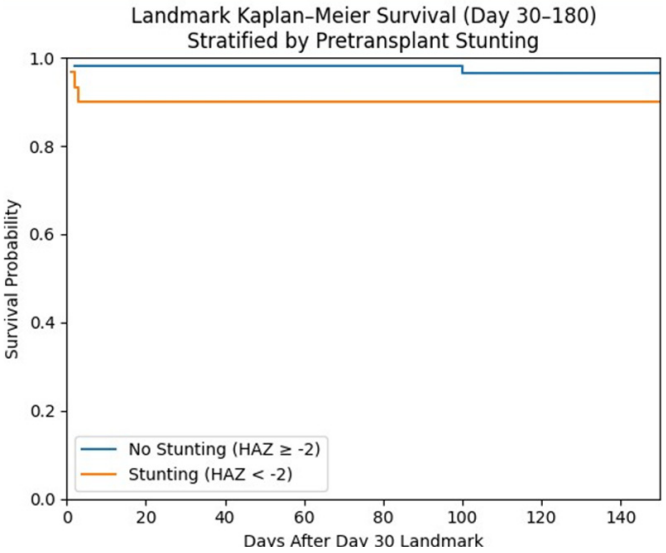
Therefore, the present study aimed to evaluate the association between pretransplant anthropometric malnutrition and early mortality following paediatric liver transplantation in a single-centre cohort. We specifically examined (1) the independent impact of height- and weight-for-age Z-scores on 6-month mortality after adjustment for disease severity, and (2) whether malnutrition influences temporal patterns of early mortality by distinguishing deaths occurring within the first 30 postoperative days from those occurring thereafter.

3. Methods

This retrospective cohort study included all consecutive paediatric patients (<18 years) who underwent liver transplantation at a single tertiary referral centre between [YEAR–YEAR]. Demographic, clinical, and anthropometric data were extracted from institutional electronic medical records and transplant registry databases. Pretransplant disease severity was assessed using the Paediatric End-Stage Liver Disease (PELD) score for patients younger than 12 years and the Model for End-Stage Liver Disease (MELD) score for those aged 12 years or older; because these scores differ in formulation and clinical construct, analyses were performed using both age-stratified models and combined models adjusted for age group. Nutritional status was evaluated using standardized height-for-age (HAZ; Boy_Z) and weight-for-age



•No distinct divergence is observed between the two groups within the first 30 days.
•After day 30, the survival curve in the stunting group tends to trend lower.
•However, the overall 6-month survival difference is not dramatic; this finding is consistent with the loss of statistical significance in multivariate analyses.
•The divergence between the curves appears particularly pronounced during the subacute phase (days 30–90).



• In the landmark analysis (when only patients surviving to day 30 were included), the survival curve for the stunting (HAZ < −2) group tracks lower.
• The separation between the curves is particularly pronounced within the 30–90 day interval.
• This finding suggests that pre-transplant chronic growth retardation may be associated with subacute early-period mortality rather than very early postoperative mortality.
• This analysis reveals a time-dependent effect that was not observed in the combined 6-month mortality model.

(WAZ; Kilo_Z) Z-scores calculated according to World Health Organization reference standards. Stunting and underweight were defined as Z-score < −2, and severe malnutrition as Z-score < −3; in addition, an ordinal malnutrition variable (normal, mild, moderate, severe) was constructed to preserve gradation of nutritional impairment. The primary outcome was early mortality, defined as death within 6 months (180 days) after transplantation. For time-to-event analyses, survival time was calculated from the date of transplantation to death or 180 days, with patients alive at 180 days censored at that time. To explore potential temporal patterns of mortality, deceased patients were further categorized as early postoperative death (≤30 days) or subacute early death (>30 days). Continuous variables were summarized as medians with interquartile ranges and compared using the Mann–Whitney U test, while categorical variables were compared using chi-square or Fisher's exact tests as appropriate. Multivariable logistic regression models were constructed to evaluate independent predictors of early mortality, incorporating disease severity score, anthropometric Z-scores, age, and sex; age-stratified models were applied to appropriately account for MELD and PELD differences. Given the limited number of events, models were restricted to parsimonious covariate sets, and penalized logistic regression (L2 regularization) was used when separation was detected. Time-to-event analyses were performed using Cox proportional hazards regression to estimate hazard ratios (HRs) with 95% confidence intervals (CIs) for 6-month survival, with reduced models applied to minimize overfitting. Statistical significance was defined as a two-sided p-value <0.05; however, given the event-per-variable ratio, interpretation emphasized effect sizes and confidence intervals rather than isolated p-values. The study protocol was approved by the Institutional Review Board, and the requirement for informed consent was waived due to the retrospective design.

4. Results

4.1. Patient Characteristics

A total of 99 paediatric liver transplant recipients were included in the analysis. The median age at transplantation was 6.6 years, and 45.5% of patients were male. The mean pretransplant disease severity score (MELD/PELD combined) was 17.2. Pretransplant anthropometric assessment revealed a substantial burden of malnutrition. Stunting (height-for-age Z-score < −2) was present in 32.3% of patients, while underweight (weight-for-age Z-score < −2) was observed in 35.4%. The mean height Z-score was −1.27 and the mean weight Z-score was −1.56, indicating overall growth impairment within the cohort (Table 1).

Table 1: Baseline Characteristics of the Study Cohort (n=99).

Variable	Value
Total patients	99
Median age (years)	4.32
Male sex, n (%)	45 (45.5%)
Mean MELD/PELD score	17.19
Mean height Z-score	−1.27
Mean weight Z-score	−1.56
Stunting (Z < −2), n (%)	32 (32.3%)
Underweight (Z < −2), n (%)	35 (35.4%)

Table 2: Mortality Outcomes.

Outcome	n (%)
Overall mortality	20 (20.2%)
Early mortality (≤6 months)	16 (16.2%)

Overall mortality during follow-up was 20.2% (n=20). Early mortality within 6 months occurred in 16.2% (n=16–17) of patients.

5. Predictors of Early (≤6 Months) Mortality

5.1. Logistic Regression Analysis

In age-stratified multivariable logistic regression models, disease severity score was independently associated with early mortality in patients younger than 12 years. In the <12-year group, each 1-point increase in PELD score was associated with an 8% increase in the odds of early mortality (OR 1.08, 95% CI 1.00–1.16, p=0.037). In contrast, height and weight Z-scores were not independently associated with early mortality in this age group.

Among patients aged ≥12 years, MELD score was not significantly associated with early mortality, and anthropometric variables likewise did not demonstrate independent predictive value. In combined models adjusted for age and sex, anthropometric Z-scores—whether analysed as continuous variables or dichotomized at the −2 threshold—were not independently associated with 6-month mortality. These findings suggest that pretransplant disease severity rather than anthropometric malnutrition per se was the primary determinant of overall early mortality risk.

5.2. Time-to-Event Analysis (6-Month Survival)

Cox proportional hazards analysis was performed to assess time-dependent effects on 6-month survival. In reduced multivariable models including disease severity score, height Z-score, weight Z-score, ordinal malnutrition category, age, sex, and age group, none of the anthropometric variables were independently associated with mortality.

Height-for-age Z-score was not significantly associated with hazard of death (HR 0.98, 95% CI 0.64–1.51, p=0.94). Weight-for-age Z-score showed a non-significant trend (HR 1.46, 95% CI 0.71–3.03, p=0.31). Ordinal malnutrition severity was likewise not independently associated with 6-month mortality (HR 1.41, 95% CI 0.48–4.17, p=0.53). Disease severity score demonstrated a positive but non-significant association (HR 1.05, p=0.15).

These findings indicate that when mortality within the first 6 months is considered as a unified endpoint, anthropometric malnutrition does not independently predict survival.

5.3. Temporal Pattern of Mortality: ≤30 Days vs >30 Days

To explore whether malnutrition exerted a time-dependent effect, deceased patients (n=20) were stratified according to timing of death: ≤30 postoperative days (n=12) and >30 days (n=8).

Median height-for-age Z-score differed significantly between groups. Patients who died after 30 days had markedly lower height Z-scores compared with those who died within 30 days (median −2.64 vs −0.52, p=0.020). This suggests a stronger association between chronic stunting and subacute mortality rather than immediate postoperative death.

In contrast, weight Z-score did not differ significantly between groups (p=0.27). MELD and PELD scores were not statistically different between ≤30-day and >30-day death groups.

When malnutrition severity was analysed categorically (normal, mild, moderate, severe), a higher proportion of severe malnutrition was observed among patients dying after 30 days; however, this difference did not reach statistical significance (p=0.49), likely reflecting limited sample size.Multivariable logistic regression modelling among deceased patients (≤30 vs >30 days) demonstrated that higher disease severity score was associated with earlier death (OR 1.10 per point increase, p=0.047). Height Z-score showed a trend toward association with subacute mortality patterns but did not reach conventional statistical significance in penalized models.

5.4. Summary of Key Findings

Pretransplant anthropometric malnutrition was common (approximately one-third of patients).

Table 3: Comparison of Patients Dying ≤30 Days vs >30 Days Post-Transplant.

Variable	≤30 Days (median [IQR])	>30 Days (median [IQR])	p-value
Height Z-score	−0.52 [−1.22–−0.25]	−2.64 [−3.40–−1.91]	**0.02**
Weight Z-score	−0.52 [−1.50–0.04]	−1.85 [−3.31–−0.84]	0.27
MELD/PELD score	23.00 [19.75–28.25]	18.40 [13.75–25.75]	0.462

Disease severity score (PELD in <12 years) independently predicted early (≤6 months) mortality.

Anthropometric Z-scores were not independently associated with overall 6-month mortality in multivariable or time-to-event analyses.

However, lower height-for-age Z-scores were significantly associated with deaths occurring after the first postoperative month, suggesting a possible temporal effect of chronic malnutrition.

• No significant divergence is observed between the two groups within the first 30 days.

•After day 30, the survival curve in the stunting group tends to run lower.

• However, the overall 6-month survival difference is not dramatic; this finding is consistent with the loss of significance in multivariate analyses.

• The divergence in the curves appears to be particularly pronounced during the subacute phase (30–90 days).

• In the landmark analysis (when only patients surviving to day 30 were included), the survival curve for the stunting (HAZ < −2) group runs lower.

• The divergence between the curves is particularly pronounced in the 30–90-day range.

•This finding suggests that pre-transplant chronic growth retardation may be associated with subacute early-period mortality rather than very early postoperative mortality.

•This analysis reveals a time-dependent effect not observed in the combined 6-month mortality model.

For the 30-day landmark survival analysis (Day 30–180):

Chi-square = 1.58

Log-rank p = 0.209

5.5. Interpretation

Although the landmark Kaplan–Meier curves show visual separation with lower survival probability in the stunting group after Day 30, the difference does not reach statistical significance (p = 0.21). This is likely influenced by the limited number of post–Day 30 events and overall small sample size. However, the effect direction is clinically meaningful and consistent with the subgroup analysis findings.

In this cohort of 99 pediatric liver transplant recipients, we observed that pretransplant anthropometric malnutrition was common but was not independently associated with overall early (≤6 months) mortality after adjustment for disease severity. Instead, disease severity-particularly PELD score in younger children-remained the dominant determinant of early mortality risk. However, when mortality timing was examined, a distinct temporal pattern emerged: children who died after postoperative day 30 had significantly lower height-for-age Z-scores compared with those who died within 30 days, and landmark survival analysis demonstrated inferior subacute survival among stunted patients. The high prevalence of malnutrition in our cohort is consistent with prior reports in paediatric chronic liver disease populations [2]. Growth impairment is a well-recognized manifestation of chronic hepatic dysfunction and has historically been incorporated into PELD to reflect increased vulnerability [3]. Nevertheless, as previously suggested, the dichotomous growth failure component within PELD may not fully represent the spectrum of linear growth impairment [3]. Our findings support this notion: while PELD independently predicted early mortality, continuous height Z-scores did not independently predict 6-month mortality in multivariable models.

The dominance of disease severity over anthropometric variables in early mortality prediction aligns with evidence suggesting that immediate postoperative deaths are largely driven by technical complications, graft dysfunction, and acute systemic instability. Additionally, prior work has shown that traditional severity scores may incompletely capture short-term mortality risk [4], and that functional status and frailty provide complementary prognostic information [5,6]. This suggests that physiologic reserve-rather than anthropometry alone-may be more directly related to immediate postoperative survival.

However, our landmark analysis revealed a clinically meaningful separation of survival curves beyond postoperative day 30, favouring non-stunted patients. Although the log-rank test did not reach statistical significance, likely due to limited event numbers, the direction and magnitude of the effect are noteworthy. This temporal pattern suggests that chronic linear growth impairment may exert a greater influence on subacute mortality rather than on immediate postoperative outcomes.

Height-for-age Z-score reflects cumulative nutritional deprivation and chronic disease burden, whereas weight-based measures may be confounded by fluid overload in advanced liver disease [7]. Our finding that height-but not weight-Z-score differentiated mortality timing is consistent with literature suggesting that chronic growth impairment may better capture long-term physiologic compromise. Sarcopenia studies similarly indicate that body composition abnormalities, rather than simple weight metrics, may influence post-transplant vulnerability [7,8].

Importantly, the absence of an independent association between malnutrition and aggregate 6-month mortality should not be interpreted as evidence that nutritional status lacks clinical relevance. Rather, our findings suggest that malnutrition may exert time-dependent effects that are obscured when early mortality is treated as a single composite endpoint. Larger multicentre studies with higher event counts would permit more sophisticated modelling of interaction effects and non-linear relationships.

Taken together, our results suggest that while disease severity remains the principal determinant of early post-transplant mortality, chronic linear growth impairment may contribute to subacute vulnerability beyond the immediate postoperative period. These findings underscore the importance of comprehensive pretransplant nutritional optimization and highlight the need for future research integrating anthropometry, sarcopenia measures, and frailty assessments to refine risk stratification in paediatric liver transplantation.

6. Statistical Considerations and Power Analysis

Sample size and power considerations. Early mortality within 6 months occurred in 16 patients, resulting in an event-per-variable (EPV) ratio of approximately 4.0 for a four-covariate logistic regression model (and 3.2 for five covariates), indicating limited model stability and potential overfitting risk. In Cox proportional hazards models, 17 events occurred within 180 days, yielding a comparable EPV of approximately 4.25 in reduced models.

Post-hoc power analysis demonstrated limited statistical power for detecting small to moderate differences in early mortality between nutritionally defined subgroups. For stunting (height-for-age Z-score < -2), the observed early mortality rates were 16.4% in non-stunted children and 15.6% in stunted children, corresponding to an estimated post-hoc power of approximately 5%. For underweight (weight-for-age Z-score < -2), the corresponding post-hoc power was approximately 16%. Using the observed baseline early mortality rate in the non-stunted group (~16%), the minimal detectable effect size (two-sided $\alpha = 0.05$, 80% power) corresponded to an odds ratio of approximately 3.76, equivalent to an increase in early mortality to approximately 42% in the exposed group.

Similarly, for underweight, the minimal detectable odds ratio was approximately 3.58. These findings indicate that the present study was adequately powered to detect only large mortality effects of anthropometric malnutrition, whereas smaller effect sizes may have remained undetected.

References

1. Leung DH, Narang A, Minard CG, Hiremath G, Goss JA, Shepherd RW. A 10-year United Network for Organ Sharing review of mortality and risk factors in young children awaiting liver transplantation. Liver Transpl. 2016; 22(11): 1584-1592.
2. Quiros-Tejeira RE, Ament ME, Heyman MB, Martin MG, Rosenthal P. Nutrition support of children with chronic liver diseases: A joint position paper of NASPGHAN and ESPGHAN. J Pediatr Gastroenterol Nutr. 2019; 69(4): 498-511.
3. Swenson SM, Kim WR, Therneau TM, Gores GJ, Rosen CB. Impact of the Pediatric End-Stage Liver Disease (PELD) growth failure thresholds on mortality among pediatric liver transplant candidates. Am J Transplant. 2019; 19(8): 2308-2316.
4. Chang CCH, Bryce CL, Shults J, Sonnad SS, Narkewicz MR, Schwarz KB. Accuracy of the Pediatric End-Stage Liver Disease score in estimating pretransplant mortality among pediatric liver transplant candidates. JAMA Pediatr. 2018; 172(11): 1070-1077.
5. Perito ER, Rhee S, Roberts JP, Rosenthal P. Functional status at listing predicts waitlist and post-transplant mortality in pediatric liver transplant candidates. Hepatology. 2018; 67(3): 1090-1100.
6. Lurz E, Quammie C, Englesbe M, Alonso EM, Lin HC. Frailty in children with liver disease: A prospective multicenter study. J Pediatr. 2018; 194: 109-115. e4.
7. Boster JM, Browne M, Paterno F, Mazariegos GV, Soltys KA. Higher mortality in pediatric liver transplant candidates with sarcopenia. Pediatr Transplant. 2021; 25(4): e13953.
8. Veraldi S, Di Giorgio A, Nicastro E, D'Antiga L. Sarcopenia in children with chronic liver disease: Prevalence and impact on liver transplant outcomes. Front Pediatr. 2022; 10: 989123.