Reducing Hospital Stay and Enhancing Wound Healing Through Intraoperative Cell Salvage in Spine Surgery

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ABSTRACT

Significant blood loss during spine surgery often necessitates allogeneic blood transfusion (ABT), which poses clinical and logistical challenges, including immune reactions, infection risks, and supply constraints. This retrospective cohort study assessed the clinical efficacy of intraoperative cell salvage (ICS) in reducing dependence on ABT and improving patient outcomes at Malaysia Government General Hospital (GH), Malaysia. Data from 72 patients who underwent spine surgeries between January 2023 and December 2024 were analysed. Participants were divided into two groups: 36 patients received ICS and 36 received standard transfusions. Comparative analyses using t-tests and chi-square tests evaluated transfusion requirements, wound healing, haemoglobin (Hb) trends, recovery time, hospital stay, and cost parameters. The ICS group demonstrated significantly shorter hospital stays (M = 8.4 days) compared to the non-ICS group (M = 16.9 days; $p < .001$), as well as faster recovery (M = 6.0 vs. 13.4 days; $p = .001$) and superior wound-healing outcomes ($p < .001$). No significant difference was observed in postoperative Hb levels or intraoperative packed red blood cell use, suggesting equivalent hematologic recovery between groups. Although the reduction in transfusion requirement was not statistically significant ($p = .108$), the trend favoured ICS. These findings indicate that ICS enhances clinical efficiency by promoting faster recovery, improved wound healing, and reduced hospital stay without compromising safety or haemoglobin stability. The results support broader integration of ICS into perioperative blood management in high-blood-loss spine surgeries, particularly in resource-constrained healthcare systems.

Keywords: Intraoperative cell salvage; Blood transfusion; Spine surgery; Wound healing

INTRODUCTION

Spine surgery frequently involves considerable intraoperative bleeding that necessitates blood transfusion to maintain hemodynamic stability. Allogeneic blood transfusion (ABT), the administration of donor blood, is often essential yet poses significant medical, logistical, and ethical concerns. The use of donor blood introduces risks of transfusion-transmitted infections, immunologic reactions, and prolonged postoperative recovery (Carson et al., 2021; Raykar et al., 2024). Furthermore, ABT imposes economic and supply challenges in hospitals where donor blood is limited or rare blood types are difficult to source, as seen in Sarawak's indigenous populations (Aubrey, 2021; Banji, 2024). In response, intraoperative cell salvage (ICS) has emerged as a valuable alternative. ICS is an autologous transfusion technique that collects, processes, and reinfuses a patient's shed blood during surgery, thereby minimising dependence on donor blood (Carroll & Young, 2021). Evidence shows that ICS decreases ABT rates, preserves red cell integrity, and mitigates infection risk (Cheriyan et al., 2020; Lloyd et al., 2023). However, despite its success in cardiac and orthopaedic procedures, its use in spine surgery—particularly in Malaysia—remains limited. At Sarawak General Hospital (SGH), the state's primary referral center, spine operations are routinely performed twice weekly. Given the volume and complexity of cases, the hospital blood bank faces recurring pressure to

maintain adequate donor supplies. Implementing ICS could reduce ABT dependence, optimise blood resource utilisation, and enhance surgical outcomes. This study, therefore, evaluates the clinical efficacy of ICS compared with conventional transfusion methods in spine surgery at SGH, assessing outcomes including transfusion requirements, haemoglobin stability, wound healing, hospital stay, recovery duration, and cost implications.

METHODOLOGY

This retrospective cohort study evaluated the clinical efficacy and outcomes of intraoperative cell salvage (ICS) compared with conventional allogeneic blood transfusion (ABT) among patients undergoing spine surgery at General Hospital (GH) in Malaysia. The investigation examined whether ICS reduced transfusion requirements, enhanced postoperative recovery, and optimised hospital resource utilisation in a high-volume surgical setting. Data were retrieved from the computerised operating theatre documentation system, electronic medical records, and surgical logs for procedures performed between January 2023 and December 2024. Ethical approval was obtained from the institutional Research Ethics Committee, and all data were anonymised prior to analysis. The study population comprised patients who underwent elective spine surgery within the specified period. Purposive sampling identified cases meeting the inclusion criteria: availability of complete medical records; documentation of intraoperative blood management (ICS or standard practice); and absence of conditions that could confound transfusion requirements. Patients were excluded if records were incomplete, surgery was performed emergently, or pre-existing coagulopathies were documented. A priori power analysis, with $\alpha = 0.05$ and 80% power, indicated a minimum of 36 participants per arm to detect an absolute 30% difference in transfusion rates; thus, 72 patients were enrolled, with 36 per arm. Variables extracted included age, sex, body mass index (BMI), comorbidities, estimated blood loss (EBL), haemoglobin (Hb) levels preoperatively and on postoperative days one and three, units of packed red blood cells (PRBC) transfused intraoperatively, wound-healing grade, length of stay, recovery time (days from surgery to discharge), and total hospital costs. Data were captured using structured case report forms to standardise abstraction and then analysed in IBM SPSS Statistics (Version 28). Descriptive statistics summarised cohort characteristics. Independent-samples t-tests compared continuous outcomes (e.g., EBL, Hb, length of stay), and chi-square tests examined categorical variables (e.g., wound-healing grade, comorbidities). Effect sizes (Cohen's d, Hedges' g) quantified the magnitude of between-group differences. Data integrity procedures included record cross-checking and outlier review to mitigate errors caused by documentation inconsistencies. Because the design was retrospective, causal inference is limited; however, methodological rigour and standardised protocols were applied to provide credible real-world evidence on the utility of ICS in this setting.

RESULTS

A total of 72 patients met the inclusion criteria, consisting of 45.8% males and 54.2% females. The mean age was 30.4 years (SD = 20.4), with the ICS group representing a younger cohort (M = 17.4, SD = 3.9) compared to the non-ICS group (M = 43.4, SD = 21.9). The body mass index (BMI) was significantly lower in the ICS group (M = 18.9 kg/m², SD = 3.4) than in the non-ICS group (M = 24.2 kg/m², SD = 5.9; $t(70) = -4.68$, $p < .001$). Table 1 presents the comparison of key intraoperative and postoperative variables between groups. Although estimated blood loss (EBL) was higher among ICS patients (M = 908 mL) than non-ICS patients (M = 664 mL; $p = .005$), 72.2% of ICS cases required no packed red blood cell (PRBC) transfusion, compared to 63.9% in the non-ICS group ($p = .108$). Haemoglobin (Hb) levels were comparable between groups preoperatively (ICS: M = 12.99 g/dL; non-ICS: M = 12.69 g/dL) and on postoperative days one and three ($p > .05$).

Notably, postoperative recovery indicators improved substantially among ICS patients. The mean length of hospital stay was significantly shorter (M = 8.4 days, SD = 5.9) than for the non-ICS group (M = 16.9 days, SD = 12.6; $p < .001$), while the mean recovery time from surgery to discharge was also reduced (M = 6.0 vs. 13.4 days; $p = .001$). Wound-healing outcomes were markedly better in the ICS group, with 94.4% achieving Grade 1 healing compared with 50.0% in the non-ICS cohort ($\chi^2 = 18.52$, $p < .001$).

Table 1: Comparison of Clinical and Haematologic Outcomes Between ICS and Non-ICS Groups (N = 72)

Variable	ICS Group (n = 36)	Non-ICS Group (n = 36)	p Value	Interpretation
Age (years), M ± SD	17.4 ± 3.9	43.4 ± 21.9	< .001	The ICS group is significantly younger
BMI (kg/m²), M ± SD	18.9 ± 3.4	24.2 ± 5.9	< .001	Significant difference in body composition
Estimated blood loss (mL), M ± SD	908 ± 347	664 ± 376	.005	Higher blood loss in ICS surgeries
Pre-operative Hb (g/dL), M ± SD	12.99 ± 1.48	12.69 ± 1.93	.465	No significant difference
Post-operative Hb Day 1 (g/dL)	11.11 ± 1.40	10.98 ± 2.13	.768	Comparable Hb after surgery
Post-operative Hb Day 3 (g/dL)	10.50 ± 1.35	10.54 ± 2.20	.930	Comparable Hb recovery
PRBC transfusion required (% of cases)	27.8 %	36.1 %	.108	Trend toward reduced transfusion in ICS
Length of hospital stay (days), M ± SD	8.4 ± 5.9	16.9 ± 12.6	< .001	Significantly shorter with ICS
Recovery time to discharge (days), M ± SD	6.0 ± 5.3	13.4 ± 12.3	.001	Faster recovery in ICS
Grade 1 wound healing (% of cases)	94.4 %	50.0 %	< .001	Significantly better wound healing
Hospital cost (RM), M ± SD	193.9 ± 225.3	645.4 ± 1 860.2	.153	Lower trend, not significant

Note. Hb = haemoglobin; PRBC = packed red blood cells; ICS = intra-operative cell salvage; M = mean; SD = standard deviation. Statistical significance set at $p < .05$.

Seventy-two patients met the inclusion criteria (45.8% male; 54.2% female). The overall mean age was 30.4 years (range 12–77), with a younger ICS cohort (M = 17.4 years) compared with the non-ICS group (M = 43.4 years). BMI differed significantly between groups (ICS M = 18.9 kg/m² vs. non-ICS M = 24.2 kg/m²; $p < .001$). Mean intraoperative estimated blood loss was greater in ICS (M = 908 mL) than in non-ICS (M = 664 mL; $p = .005$), reflecting selective ICS use in higher-risk procedures. Despite higher blood loss, 72.2% of ICS patients avoided intraoperative PRBC transfusion, compared with 63.9% of non-ICS patients; differences in units transfused were not statistically significant ($p = .631$). Haemoglobin trajectories were comparable: preoperative Hb averaged 12.99 g/dL (ICS) and 12.69 g/dL (non-ICS; $p = .465$); postoperative day one values were 11.11 and 10.98 g/dL, respectively; by day three, both groups averaged around 10.5 g/dL (all $p > .05$). Wound-healing outcomes differed markedly: 94.4% of ICS patients achieved Grade 1 healing versus 50.0% in non-ICS ($\chi^2 = 18.52$, $p < .001$), with higher grades of complications concentrated in the non-ICS cohort. Length of stay was significantly shorter with ICS (M = 8.4 vs. 16.9 days; $p < .001$), as was recovery time from surgery to discharge (M = 6.0 vs. 13.4 days; $p = .001$). Comorbidities were more prevalent in the non-ICS group (55.6% with at least one condition) than in ICS (19.4%; $\chi^2 = 10.02$, $p = .002$). Although total hospitalisation costs trended lower in ICS (RM194 vs. RM645; $p = 0.153$), government subsidies and procurement models limited standardisation for formal cost-effectiveness analysis.

DISCUSSION

This study adds context-specific evidence from a Malaysian tertiary centre to the international literature on intraoperative cell salvage. In a cohort of spine surgery patients, ICS was associated with significantly shorter hospital stays, faster recovery, and superior wound-healing outcomes, while maintaining haemoglobin trajectories comparable to those with conventional allogeneic transfusion. Although intraoperative PRBC usage did not differ significantly, 72% of ICS patients avoided intraoperative transfusion despite higher blood loss, suggesting that ICS enabled autologous red cell reinfusion sufficient to preserve haematologic stability.

These results align with and extend prior syntheses showing ICS reduces exposure to donor blood. The Cochrane review by Lloyd et al. (2023) reported a 56% relative reduction in transfusion in spinal surgery with ICS, whereas Cheriyan et al. (2020) demonstrated an average reduction of 0.81 allogeneic units across spine procedures. Our non-significant difference in PRBC units may reflect sample size constraints and case-mix: ICS was preferentially deployed in higher EBL cases, diluting the detectable between-group contrast. Importantly, haemoglobin trends were comparable by postoperative day three, mirroring Liu et al. (2017) who observed early postoperative Hb benefits with ICS that converged by discharge. Collectively, the pattern supports ICS as a safe conservation strategy that does not compromise haematologic recovery.

A key, underreported finding is the strong association between ICS and improved wound healing. Transfusion-related immunomodulation (TRIM) is a well-established concern associated with ABT, encompassing cytokine shifts, impaired cellular immunity, and microchimerism that can impact infection and tissue repair (Carson et al., 2021). Our observation that 94% of ICS patients achieved Grade 1 healing, compared to 50% in non-ICS patients, is consistent with the hypothesis that limiting donor exposures mitigates TRIM and downstream complications. While we cannot definitively attribute causality, the magnitude and direction of effect, alongside the absence of Hb disadvantages in ICS, argue that autologous strategies may favour tissue recovery. This aligns with broader perioperative blood management guidance, which recommends a multimodal approach utilising TXA, meticulous haemostasis, hypotensive anaesthesia, and salvage to reduce complications (Mikhail et al., 2020; Lenet et al., 2023).

From a systems perspective, ICS supports the sustainability and resilience of the blood supply. Malaysia's reliance on volunteer donors can lead to periodic shortages, and East Malaysia faces unique compatibility challenges due to rare phenotypes (Aubrey, 2021; Banji, 2024). ICS provides an on-demand autologous source that reduces pressure on blood banks, shortens hospital stay, and potentially lowers expenditure through fewer transfusion-associated events and faster throughput. Although we did not perform a formal cost-effectiveness analysis—owing to subsidy structures and non-itemised procurement the direction of the results aligns with international assessments that associate ICS adoption with downstream savings in high-blood-loss contexts (Brandão et al., 2023). Future Malaysian cost studies should incorporate micro-costing of disposables, amortised device costs, staff time, and savings from reduced length of stay and complications to inform procurement policy.

Ethically, ICS enhances respect for patient values and autonomy. Jehovah's Witnesses may decline ABT entirely, and ICS—with appropriate consent—offers a clinically acceptable alternative (Klein et al., 2018). Likewise, for patients with rare antigen profiles, ICS reduces the risk of haemolytic reactions from mismatched donor units. Institutionalising ICS within perioperative pathways, therefore, advances patient-centred care while safeguarding safety.

A critical appraisal of our findings must account for selection bias and confounding. The ICS cohort was younger with lower BMI and fewer comorbidities—factors themselves associated with better wound healing and faster recovery (Briguglio et al., 2022; Myles, 2020). While statistical testing identified significant group differences, residual confounding remains a plausible concern in any retrospective design. Moreover, greater EBL in ICS cases reflects clinical triage toward salvage in higher-risk surgeries; paradoxically, the superior outcomes in ICS despite this disadvantage strengthen the signal in favour of ICS but also complicate causal inference. Future research should use prospective allocation or randomised designs, standardise transfusion thresholds, and stratify by procedure complexity to isolate ICS effects more clearly. Pragmatic trials embedded within theatre lists at SGH could leverage existing documentation systems to minimise incremental cost.

Generalizability is enhanced by focusing on routine practice in a government hospital serving diverse populations; however, implementation fidelity matters. ICS benefits depend on timely setup, adequate suctioning of shed blood, appropriate anticoagulation and washing parameters, and staff proficiency (Carroll & Young, 2021). Investment in training Assistant Medical Officers and anaesthetic teams, along with 24/7 availability of devices and disposables, is essential. Parallel adoption of evidence-based adjuncts, such as TXA (Mikhail et al., 2020), topical haemostats (Huec et al., 2022), and strict haemostasis, can maximise salvage yield and consistency.

Finally, our findings fit within a broader movement toward patient blood management (PBM) to reduce unnecessary transfusions and improve outcomes across surgical specialities (Kiyatkin et al., 2023). PBM emphasises preoperative anaemia optimisation, minimally invasive techniques, restrained transfusion thresholds, and autologous strategies. In this PBM framework, ICS is not a standalone solution but a pivotal intraoperative pillar. For SGH, an ICS-first algorithm for anticipated high-EBL spine procedures—coupled with standard TXA, haemostatic techniques, and postoperative surveillance could serve as the basis for local guidelines and MQA-aligned quality indicators for training and audit.

CONCLUSION

In spine surgery at Malaysia General Hospital, intraoperative cell salvage was associated with a shorter length of stay, faster recovery, and superior wound-healing outcomes, while maintaining haemoglobin recovery comparable to that of conventional transfusion. Although intraoperative PRBC use was not significantly different, a favourable trend toward transfusion avoidance was observed despite higher blood loss in the ICS group. These findings support ICS as a safe and valuable component of perioperative blood management in high-blood-loss spine procedures, particularly in resource-constrained settings and populations with rare blood phenotypes or transfusion objections. Prospective studies and context-specific economic evaluations are warranted to confirm effect sizes and inform hospital-wide policy and procurement.

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