

The Size and Localization of the Liver Haemangioma – Risk Factors for Massive Post-Resection Blood Loss

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Abstract: Hepatic haemangiomas are common benign liver tumours, often detected through advanced imaging and clinically significant when large or symptomatic. The objective of this study was to determine how tumour size, location, and associated operative factors influence perioperative outcomes, specifically focusing on the risk of massive blood loss. This single-centre retrospective-prospective analysis included 101 patients with cavernous haemangioma who underwent resection or enucleation between 2010 and 2023, with retrospective cases covering surgeries from 2010 to 2020 and prospective cases from 2021 to 2023, evaluating tumour diameter, intraoperative technique, and use of vascular control manoeuvres. The sample showed intraoperative blood loss ranging from 20 ml to 400 ml, with an average of 173.5 ml. Bilateral tumours had the highest mean blood loss (249.167 ml), followed by right-sided lesions (189.286 ml), central lesions (158.571 ml), and left-sided lesions (149.255 ml). Larger tumours correlated positively with blood loss (Pearson correlation 0.333; $p=0.001$), and an increase of 1 cm in diameter corresponded to an additional 3.744 ml of bleeding. For patients with borderline hemodynamic stability, this additional 3.744 mL of bleeding could exacerbate existing circulatory challenges, potentially requiring more intensive monitoring and interventions to maintain stable hemodynamics during surgery. The Pringle manoeuvre, used in 35% of the operations, was tied to a higher observed average blood loss (223.714 ml) relative to cases without vascular inflow occlusion (146.894 ml). This study refines preoperative risk stratification based on tumour size, localization, and vascular involvement, guiding surgical techniques to minimize intraoperative blood loss in hepatic haemangioma resection.

Keywords: Pringle manoeuvre, vascular control, surgical outcomes, intraoperative management, hepatic oncology.

INTRODUCTION

Hepatic haemangiomas are among the most commonly encountered benign liver tumours, a fact that has become increasingly evident with advancements in cross-sectional imaging techniques, such as ultrasound, computed tomography (CT) scans, and magnetic resonance imaging (MRI) [1]. These imaging modalities have shifted incidental radiologic findings from mere curiosities into clinically significant entities, particularly as haemangiomas exceed certain size thresholds or begin to cause nonspecific abdominal symptoms like pain or discomfort. It is estimated that hepatic haemangiomas are present in up to 20% of the population, although many individuals remain asymptomatic. As these tumours can present with varying degrees of symptomatology and may mimic other more serious hepatic conditions, timely and accurate diagnosis is critical [2, 3]. The growing use of non-invasive imaging methods has led to a higher rate of detection, increasing the clinical importance of understanding the management and potential complications of hepatic haemangiomas. Therefore, this article aims to provide an updated and comprehensive review of the current knowledge surrounding hepatic haemangiomas, including their

diagnosis, treatment strategies, and management of potential complications, to assist clinicians in delivering more effective care for affected patients. According to Wang A, *et al.* [1], these vascular tumours can affect a substantial segment of the adult population, underscoring the significance of carefully differentiating them from alternative hepatic pathologies. Kacala A, *et al.* [2] additionally emphasize that although most haemangiomas remain asymptomatic, precise diagnostic characterization and vigilant follow-up become imperative when their growth pattern or local effects pose a risk of structural compression or other complications.

According to the anatomical observations provided by Mamone G, *et al.* [3], cavernous hepatic haemangiomas contain both an afferent and an efferent vascular bundle. The afferent component delivers arterial blood to the lesion, typically via segmental or lobar arterial branches that enter along the periphery, undergo haemangiomatous and laciform expansions, and measure approximately 3.0-8.0 mm in diameter. The efferent vascular bundle, in turn, drains the haemangioma through venous outflows connected to the hepatic and portal venous systems. Notably, branches of the portal vein may exhibit cavernous transformation reaching 10.0-50.0 mm and frequently reside near the lesion's centre.

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Despite advances in resection techniques, Torbenson M.S. [4] emphasizes that major intraoperative haemorrhage persists as the primary challenge in hepatic haemangioma surgery. The extent of blood loss typically correlates with tumour size, use or non-use of the Pringle manoeuvre (PM), specific locational factors, and adjacency to substantial venous structures. This combination of vascular complexity and variable anatomical relationships underscores the need for precise preoperative planning and rigorous surgical technique to mitigate haemorrhagic risks.

Wu S, *et al.* [5] observed that haemorrhage frequently emerges as a primary complication in the surgical management of hepatic haemangiomas, particularly those exhibiting large dimensions or intricate vascular connections, and noted that intraoperative blood loss may surpass 800 ml under such circumstances. Their findings indicate that this bleeding risk can escalate when haemangiomas reside near major venous structures or intersect multiple hepatic segments, where controlling inflow and outflow demands greater precision and extended operating time. Yang K, *et al.* [6] additionally emphasized that effective perioperative planning, including early risk stratification, targeted anaesthetic protocols, and vigilant fluid administration, remains crucial for minimizing hemodynamic instability in these high-burden cases. Prophylactic measures, such as careful dissection along relatively bloodless planes and intermittent PM, were shown to substantially reduce total blood loss.

Both studies highlighted the utility of modern adjuncts like intraoperative salvage systems and advanced haemostatic tools for mitigating haemorrhagic events. Taken together, these observations underscore the need for refined operative strategies and rigorous perioperative collaboration to safeguard patient stability when excising haemangiomas prone to elevated blood loss, thereby reinforcing the importance of meticulously tailoring both the technical and clinical management approaches for individuals harbouring vascular lesions of this nature. Despite these advancements, a critical analysis of current research reveals certain limitations that hinder the establishment of universally applicable surgical approaches for hepatic haemangioma management, thereby underscoring the need for the present study to address these gaps and refine clinical decision-making.

A principal limitation in contemporary studies on hepatic haemangioma resection lies in the narrow scope of tumour samples or surgical approaches.

Some investigations concentrate exclusively on specific lesion localizations, overlooking the diverse configurations that can alter operative strategies. Others rely on just one surgical technique, whether open resections or minimally invasive procedures, thus limiting the ability to compare different methods under varying clinical circumstances. This restricted perspective hinders the generalizability of research findings and impedes the establishment of comprehensive treatment guidelines.

The objective of this study was to fill the existing gap in hepatic haemangioma research by analysing a diverse, multicentre patient cohort, including tumours of various sizes and locations and different surgical techniques. This approach allows for a direct comparison of factors influencing surgical risk, helping to refine preoperative risk assessment and optimize intraoperative strategies. By identifying key determinants of blood loss and surgical complexity, this study aims to improve operative planning and patient outcomes.

MATERIALS AND METHODS

This investigation was conducted as a single-centre retrospective-prospective study, encompassing 101 patients with cavernous haemangioma who underwent radical surgery at the Department of Surgery of the Military Medical Academy between 2010 and 2023. A total of 52 patients were observed prospectively, while the remaining 49 were evaluated retrospectively. Of these patients, 91 had a single haemangioma, and 10 presented with two lesions. For clarity, we refer to the main lesion as the “first tumour” ($n=101$) and the additional lesion as the “second tumour” ($n=10$). The sample size provides statistical power to detect significant correlations between hemangioma size and blood loss, given the variety of locations and surgical techniques.

Regarding tumour location, 28 patients (28%) had lesions in the right hemiliver, 47 (46%) in the left, 14 (14%) in a central position, and 12 (12%) bilobar. The mean haemangioma diameter was 11.25 cm, with the smallest measuring 4 cm and the largest 35 cm. 111 surgical procedures were performed: 84 resections and 27 enucleations. The cohort was split into two groups based on the absence or presence of synchronous procedures (e.g., additional resections unrelated to haemangioma). Synchronous operations are surgical procedures that are performed simultaneously or in close connection during a single surgical session. These may be procedures aimed at treating several

pathological processes that require surgical intervention, such as resection of several tumors or removal of other concomitant lesions during the main operation. An example of a synchronous operation would be when a patient undergoes surgical treatment for a liver hemangioma and gallbladder removal at the same time, or when several resections of affected areas of the liver located in different segments are performed. Identifying and providing examples of synchronous procedures will help readers better understand the complexity of such operations and their impact on surgical planning and postoperative recovery.

The method for measuring blood loss in this study involved direct assessment through the collection of blood that spilled into specially prepared containers during surgery. The amount of blood lost during each stage of the operation was recorded in milliliters using a surgical blood collection system, and the volume of blood used for transfusion after the operation was also taken into account. All patients were carefully monitored to determine total blood loss, and the volume of blood loss before and after the Pringle maneuver (PM) was assessed separately.

Potential limitations of this approach may arise due to difficulties in measurement accuracy, as some blood

may remain in the surgical field, tissues, or instruments, which may affect the result. In addition, this method does not take into account microscopic blood loss, which may not be noticeable during the stages of surgical preparation or recovery. Technical aspects of the operation, such as the use of meshes or devices to reduce blood loss, can alter the actual amount of blood loss, which is also not always correctly taken into account. Variations in the anatomical characteristics of patients can also lead to significant differences in actual blood loss, making it difficult to standardize the method.

Table 1 summarizes the principal operative characteristics of the study cohort, which consisted of 101 patients who underwent surgery for hepatic haemangiomas. It compares two groups: those who underwent synchronous operations (30 patients) and those who did not (71 patients). The table presents various operational factors, including the type of operation, surgical approach, use of the PM, intraoperative blood loss, operating time, postoperative recovery, and complications based on the Dindo-Clavien classification.

Table 1 provides an overview of the operative characteristics and outcomes for 101 patients who underwent surgery for hepatic hemangioma. Most

Table 1: Characteristics of Operational Factors

		Total number of patients (n=101)	No synchronous operations (n=71)	With synchronous operations (n=30)
Type of operation resection enucleation		80 (80%) 21 (20%)	56 (55.5%) 15 (14.8%)	24 (23.7%) 6 (6%)
Type of operation open laparoscopic		71 (70%) 30 (30%)	45 (44.6%) 26 (25.7%)	26 (25.7%) 4 (4%)
Pringle	yes	35 (35%)	26 (25.7%)	9 (8.9%)
	no	66 (65%)	45 (44.6%)	21 (20.7%)
Intraoperative blood loss (ml)		173.5	158.6	208.6
Operating time (min)		184.5	117.5	215.3
Postoperative hospital period(days)		6.28	5.9	7.17
Complications (Dindo-Clavien)	I-II gr.	12	7	5
	III-IV gr.	6	3	3
AST on the 3rd p.o. day		74.7	82.1	57.2
ALT on the 3rd p.o. day		91.8	100.3	71.7
INR on the 3rd p.o. day		1.1	1.11	1.12
Bilirubin on the 3rd p.o. day		13.06	13.4	11.8
Haemoglobin on the 3rd p.o. day		119	120	116
Lactat postoperatively		1.95	1.97	1.88

Source: compiled by authors.

patients (80%) underwent resection, while 20% underwent enucleation. Regarding the type of surgical approach, 70% of the operations were performed using an open method, and 30% were performed laparoscopically. In the group with synchronous operations, there was a lower percentage of laparoscopic interventions, which may indicate the greater complexity of these operations, which required a traditional open approach.

The PM was used in 35% of operations, while in the group without synchronous operations, the use of PM was 44.6%. This may indicate that the maneuver was used more often in operations that did not involve additional interventions, possibly due to the lower complexity of such operations. The mean blood loss was higher in the synchronous surgery group (208.6 ml) compared to the non-synchronous surgery group (158.6 ml). This can be explained by the greater complexity and duration of operations involving additional resections or other interventions. The duration of the operation was also longer in the group with synchronous operations (215.3 minutes) compared to the group without synchronous operations (117.5 minutes). This supports the assumption that additional procedures or interventions require more time to perform.

The length of postoperative hospital stay was slightly longer in the synchronous surgery group (7.17 days) compared to the non-synchronous surgery group (5.9 days), which also indicates a more complicated postoperative period. In terms of the level of complications, the situation was similar in both groups, with most complications classified as minor (I-II according to the Dindo-Clavien classification), although more serious complications (III-IV) were also noted, indicating potentially more severe outcomes in more complex operations. Liver enzyme levels (AST, ALT, INR, bilirubin) were slightly higher in the synchronous surgery group, particularly for AST and ALT, indicating a greater burden on the liver due to more complex procedures. However, these values remained within the normal range for postoperative liver stress. Hemoglobin and lactate levels were similar between groups, indicating similar levels of blood loss and metabolic stress.

Statistical analysis of the obtained data was performed using Pearson's correlation coefficient to assess relationships between variables, one-way analysis of variance (ANOVA) to compare differences among groups, and post-hoc testing with the Least

Significant Difference (LSD) method to identify specific pairwise distinctions.

The LSD method is a post-hoc statistical test used after an ANOVA to make pairwise comparisons between group means. When an ANOVA indicates that there are significant differences among the groups, the LSD method helps to identify which specific groups differ from each other. The LSD test is applied to the means of the groups to determine if the difference between any two groups is statistically significant. The LSD test is based on the principle of comparing the difference between group means to a critical value derived from the standard error of the mean differences. If the absolute difference between the group means exceeds this critical value, the difference is considered statistically significant.

One of the main advantages of the LSD method is its simplicity and ability to detect differences between all pairs of groups. It has some limitations, primarily the risk of Type I errors (false positives) when multiple comparisons are made. This risk arises because the LSD method does not adjust for the increased likelihood of finding a significant result simply due to the number of comparisons being made. To mitigate this risk, other more conservative methods, such as the Tukey or Bonferroni tests, may be used, which adjust for multiple comparisons but are generally more stringent.

RESULTS

Recent advances in imaging technologies, such as contrast-enhanced ultrasound (CEUS), dynamic contrast-enhanced MRI, and 3D imaging, have significantly improved the detection and characterization of hepatic lesions. CEUS allows for real-time, high-resolution imaging with enhanced vascular details, improving tumour delineation. Dynamic contrast-enhanced MRI offers superior tissue characterization and accurate assessment of tumour perfusion, aiding in the differentiation of benign and malignant lesions. 3D imaging provides a detailed, volumetric view of liver anatomy, assisting in surgical planning and precise tumour localization. These advancements enable better preoperative risk assessment, guiding surgical strategies to minimize complications and improve patient outcomes.

The neoplasms are divided into four distinct groups based on their location: right-sided, left-sided, central, or bilateral [7]. The recorded blood loss ranges from 20 ml to 400 ml. The entire sample shows an average

blood loss of 173.515 ml, accompanied by a standard deviation of 89.352, reflecting considerable variability. This variability is primarily influenced by tumour localization, with bilateral haemangiomas showing the highest blood loss, followed by right-sided lesions. Figure 1 illustrates the variation in blood loss during different types of interventions based on tumour localization. The data shows how blood loss fluctuates across various groups of right-sided, left-sided, central, and bilateral haemangiomas during surgery. From this overall perspective, several differences emerge when comparing the various localization groups in detail.

The Figure 1 reveals clear differences in mean blood loss associated with the localization of haemangiomas. Bilateral haemangiomas have the highest average blood loss (249.167 ml), followed by right-sided haemangiomas at 189.286 ml. Central tumours show an intermediate blood loss of 158.571 ml, while left-sided tumours have the lowest average blood loss at 149.255 ml. These findings suggest that bilateral haemangiomas, which likely involve larger or more complex vascular territories, pose a higher risk for significant blood loss during surgery. In contrast, left-sided haemangiomas, being typically smaller or involving less vascularized regions, result in lower blood loss. The variation in blood loss across the localization groups emphasizes the importance of tailoring surgical approaches based on tumour location to mitigate haemorrhage risks.

ANOVA indicates statistically significant differences across these localization groups ($F=4.973$; $p=0.003$).

Post-hoc testing with the LSD method highlights specific pairwise distinctions. Right-sided tumours exceed left-sided tumours in blood loss by about 40.03 ml, and right-sided tumours surpass central tumours by roughly 59.881 ml. Bilateral localization reflects the highest blood loss, exceeding that of the left-sided group by approximately 99.911 ml and surpassing the central group by around 90.595 ml. No significant difference emerges between the left-sided and central categories. This pattern suggests that individuals with bilateral or right-sided haemangiomas are more susceptible to higher intraoperative blood loss than those with left-sided or central lesions, which has significant clinical implications. Bilateral and right-sided haemangiomas often involve more complex vascular structures, requiring extensive resections and leading to greater blood loss [8, 9]. In clinical terms, this increased blood loss can elevate the risk of complications such as hypovolemic shock, prolonged recovery, and the need for blood transfusions, which may further complicate postoperative care.

Higher blood loss is associated with greater postoperative morbidity, including liver dysfunction, delayed healing, and extended hospital stays. Moreover, patients with bilateral or right-sided lesions may face a higher likelihood of transfusion-related complications. Therefore, recognizing these risks is crucial for preoperative planning. Surgeons can take preventive measures, such as optimizing vascular control and preparing for potential transfusions, to mitigate blood loss and improve patient outcomes [10,

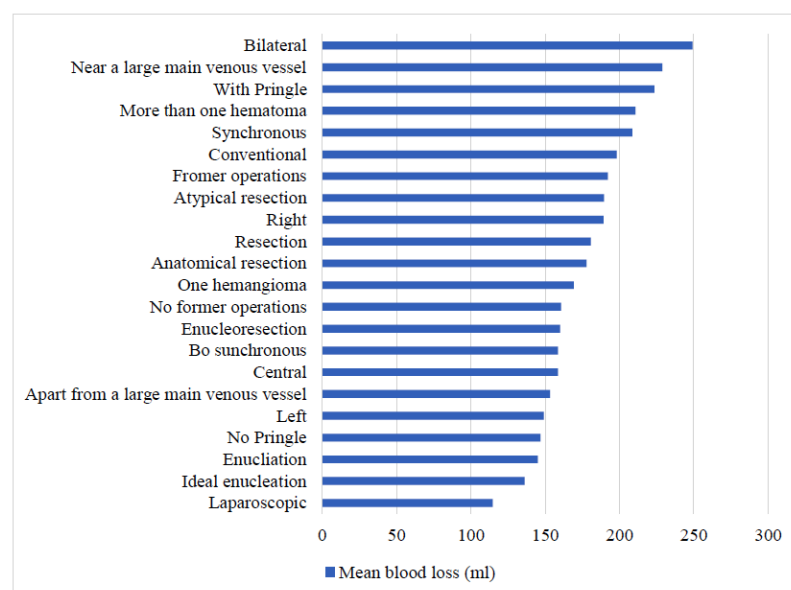


Figure 1: Blood loss during different types of interventions.

Source: compiled by authors.

11]. These findings suggest that right-sided and bilateral haemangiomas may warrant distinct surgical strategies to mitigate the risk of excessive intraoperative blood loss. Given their association with higher bleeding volumes, a more proactive approach to vascular control, including early identification and ligation of feeding vessels, optimized use of the PM, and consideration of adjunctive haemostatic techniques, may be particularly beneficial in these cases.

Several factors may account for the elevated bleeding risk associated with bilateral involvement. Haemangiomas that occupy both the right and left lobes of the liver often demand a more extensive surgical field [12, 13]. The liver's dual blood supply, consisting of the hepatic artery and the portal vein, can present a complex vasculature, especially when both lobes require mobilization or partial resection. Bilateral disease may require the surgeon to expose and control multiple vascular branches, including segmental or subsegmental vessels spanning larger sections of the hepatic parenchyma. Such expanded dissection naturally heightens the potential for vascular injury and more pronounced haemorrhage [14, 15]. Bilateral lesions might complicate the surgeon's ability to isolate feeding vessels early, since pathology extends across distinct anatomic boundaries, prolonging operative time and increasing the likelihood of inadvertent bleeding [16].

Right-sided haemangiomas also appear to induce higher intraoperative blood loss when compared to central and left-sided tumours. The right lobe of the liver constitutes a substantial portion of the organ, typically containing a complex vascular architecture with multiple large portal vein branches and hepatic artery subdivisions supplying the region [17, 18]. The relatively larger size of the right lobe and its intricate vasculature can make surgical resections more challenging [19]. Manoeuvres such as mobilization of the right liver, dissection of the retrohepatic vena cava, and ligation of right hepatic veins might lead to an elevated risk of bleeding if the haemangioma is situated in an area with dense vascular connections. Moreover, involvement of the dome region adjacent to the diaphragm can increase technical difficulty, further raising the chance of venous or arterial injury [20, 21].

The pliability of the liver parenchyma surrounding the tumor plays an important role in the ease of dissection and, accordingly, in the level of intraoperative blood loss. In patients with cirrhotic liver, the parenchyma often becomes more fibrous and

dense, which complicates the dissection process and increases the risk of bleeding [22, 23]. This is because cirrhosis causes changes in the anatomical structure of the liver, including dilation of blood vessels, displacement of normal tissue structure, and formation of fibrous adhesions. As a result of these changes, surgery on such a liver often requires additional effort to control bleeding, as the parenchyma becomes less elastic and vascular damage may be more pronounced.

In patients with non-cirrhotic livers, the tissue is usually softer and more elastic, which facilitates the dissection process and reduces the likelihood of significant bleeding [24]. However, even in such patients, if the tumor has a large vascular network or is located close to large venous structures, the risk of blood loss can be significant. In these cases, the increased vascular network can lead to more difficult operations, even in the presence of healthy liver parenchyma. Thus, the compliance of the liver parenchyma significantly influences surgical strategies and methods of bleeding control. In patients with cirrhosis, bleeding must be monitored more carefully and additional hemostatic methods must be used, as the greater tissue density complicates the process of tissue separation and can cause greater blood loss [25, 26].

In contrast, left-sided haemangiomas display the lowest recorded mean blood loss, at 149.255 ml. One explanation involves the often-smaller volume of the left lobe relative to the right, allowing for simpler mobilization and vascular control. The left hepatic artery and its branches can sometimes be more straightforward to isolate, and the left portal vein is generally of smaller calibre compared to the right portal vein. These anatomical characteristics might collectively reduce the extent of dissection and lower the probability of massive blood loss. The left lobe is confined to fewer segments than the right lobe, limiting the number of segmental branches requiring ligation or cauterization during resection. As a result, left-lateral or left-median segmental resections may lead to a more contained surgical field, diminishing the likelihood of vascular injury [27, 28].

Central haemangiomas exhibit a mean blood loss of 158.571 ml, reflecting a value between those reported for right-sided and left-sided lesions. This category's location usually involves segments adjacent to the porta hepatis or the middle hepatic vein. Resections can demand careful identification and control of both

hepatic arterial inflow and portal venous inflow to the involved segments. Even so, central tumours do not present a statistically significant difference in mean blood loss compared to left-sided tumours. One possible explanation is the relatively direct approach to isolating feeding vessels in a central lesion, provided that advanced imaging techniques clearly delineate the arterial and venous structures. If precise vascular control is achieved early in the operation, the net volume of blood lost may remain moderate, thus aligning central tumours more closely with left-sided rather than right-sided or bilateral presentations [29, 30]. Table 2 presents general information about blood loss during surgery for haemangiomas, grouped by tumour localization (right, left, central, and bilateral). It includes descriptive statistics such as the number of cases (N), mean blood loss, standard deviation, standard error, 95% confidence interval, and the minimum and maximum blood loss values for each localization group.

The Table 2 highlights the variation in blood loss across different tumour localizations. The group with bilateral haemangiomas showed the highest mean blood loss at 249.167 ml, while the left-sided group had the lowest mean blood loss at 149.255 ml, a nearly 100 ml difference. This suggests that the extent and distribution of the tumour within the liver significantly impact blood loss. Bilateral haemangiomas often involve a larger portion of the hepatic parenchyma, requiring resection across multiple segments of both lobes, which increases surgical complexity and blood loss. On the other hand, left-sided lesions are typically smaller and more localized, leading to fewer vascular pedicles requiring control and, consequently, less blood loss. Additionally, the higher standard deviation and wider confidence interval for the bilateral group (106.4688 and [181.520, 316.814] ml) indicate a

greater variability in blood loss, likely due to the complexity of these surgeries. In contrast, left-sided haemangiomas, with a lower standard deviation (82.8433), suggest a more consistent surgical outcome with lower blood loss across the cases.

The nearly 100 ml difference in mean blood loss between bilateral haemangiomas and left-sided haemangiomas emphasizes the influence of tumour extent and distribution within the liver. Bilateral haemangiomas typically involve a larger percentage of the hepatic parenchyma, requiring resection or partial removal in multiple segments across both lobes. This scenario likely increases operative time, the number of vascular pedicles requiring control, and, inevitably, the total volume of bleeding encountered. In comparison, localized left-sided lesions demand a narrower operative corridor and fewer vascular pedicles to handle.

The wide range of bleeding (20 ml to 400 ml) underscores the degree to which factors such as patient anatomy, haemangioma size, operative technique, and local hemodynamic conditions can drive substantial variability. Individual variations in hepatic arterial branching patterns, the presence of accessory vessels, and the degree of collateral circulation around the lesion may influence the final volume of blood loss [31, 32]. The data nonetheless confirm a pattern: the bilateral category stands out with the largest mean blood loss, right-sided lesions occupy an intermediate to high range, and the lowest average bleeding is observed with left-sided and central tumours.

Possible reasons include a more elaborate vascular territory in the right lobe, the more extensive involvement of hepatic tissue in bilateral cases, and potentially increased difficulty in isolating critical

Table 2: Tumour Localization and Blood Loss Characteristics for Individual Groups

Descriptive								
Blood loss (ml)								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower bound	Upper bound		
Right	28	189.286	74.3828	14.0570	160.443	218.128	80.0	400.0
Left	47	149.255	82.8433	12.0839	124.932	173.579	30.0	350.0
Central	14	158.571	88.6529	23.6935	107.385	209.758	20.0	300.0
Bilateral	12	249.167	106.4688	30.7349	181.520	316.814	100.0	400.0
Total	101	173.515	89.3520	8.8909	155.876	191.154	20.0	400.0

Source: compiled by authors.

vessels early in the procedure. Conversely, localizations in the left lobe and central regions appear less prone to extreme blood loss, although caution remains necessary for any hepatic surgery, especially when dealing with a lesion known to be vascular in nature, such as a haemangioma.

Certain surgical factors appear closely intertwined with intraoperative bleeding in liver haemangioma resections. Among these factors, the influence of a lesion's proximity to large venous structures, the application of the PM, and the tumour's size emerge as particularly notable. The data point to meaningful variations in blood loss linked to each of these variables, suggesting that an operation's complexity, inherent anatomical challenges, or surgeon-initiated techniques can amplify or mitigate total haemorrhage.

One factor that stands out involves lesions located near major venous pathways. These venous pathways can be critical in the context of liver resections, as they may carry substantial blood flow that is difficult to control once disrupted. Surgeons often need to adopt more meticulous dissection strategies when approaching these sites, dedicating additional time to isolate or protect such vessels to prevent inadvertent or excessive bleeding [33, 34]. As indicated in Table 3, procedures performed in close proximity to a large venous vessel demonstrate higher blood loss compared to those where lesions do not abut major veins. The same data also shows longer average operating times in the presence of large vessel

adjacency, suggesting that numerous haemostatic measures, stepwise tissue separation, or repeated clamp-and-release manoeuvres might be necessary to maintain adequate visualization and stable blood pressure.

The Table 3 clearly shows that haemangiomas located near large venous vessels result in higher blood loss and longer operating times. Procedures where the lesions were adjacent to major veins had a mean blood loss of 228.889 ml, compared to 153.311 ml in cases where the lesions were not near large vessels. The greater blood loss in these cases reflects the increased surgical complexity due to the need for more precise dissection and control over major venous structures.

The operating time for surgeries involving haemangiomas near large vessels was significantly longer, with a mean of 228.333 minutes compared to 168.514 minutes for those not adjacent to major veins. This longer operating time likely reflects the additional steps required to manage blood flow, including haemostatic measures, stepwise tissue separation, and repeated clamp-and-release manoeuvres to ensure adequate visualization and stable blood pressure. These findings highlight the critical role of tumour proximity to large venous structures in determining surgical difficulty, with implications for surgical planning and the need for specialized techniques to manage these more challenging cases effectively.

Table 3: Blood Loss and Operating Time for Haemangiomas Adjacent to a Large Venous Vessel

Group Statistics					
	Proximity to a large venous vessel	N	Mean	Std. deviation	Std. error mean
Blood loss (ml.)	No	74	153.311	85.1842	9.9025
	Yes	27	228.889	77.3769	14.8912
Operating time (min.)	No	74	168.514	56.6999	6.5912
	Yes	27	228.333	55.6258	10.7052

Source: compiled by authors.

Table 4: Results of t-Test Comparing mean Blood Loss in Operations near a Large Venous Vessel and other Operations

Independent Samples Test										
Assumptions		Levene's Test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. Error difference	95% confidence interval of the difference	
									Lower	Upper
Blood loss(ml)	Equal variances assumed	0.603	0.439	-4.040	99	0.000	-75.5781	18.7073	-112.6974	-38.4587

Source: compiled by authors.

Table 4 presents the results of an independent samples t-test comparing the mean blood loss between operations performed near a large venous vessel and those performed without such vascular involvement. The table includes the results of Levene's test for equality of variances, the t-test statistic, degrees of freedom, and the significance level, along with the mean difference in blood loss and its 95% confidence interval.

The results presented in Table 4 show a statistically significant difference in blood loss between operations performed near a large venous vessel and those without such proximity. The t-test for equality of means reveals a mean difference of -75.58 ml, with a p-value of 0.000, indicating that the difference is statistically significant at the 0.05 level. This suggests that haemangiomas located near major venous vessels result in significantly higher blood loss during surgery compared to those further from large vessels.

Although the average difference in blood loss (75.58 ml) may seem modest, it can become clinically important, especially during complex hepatic procedures. In these settings, even small disruptions to large-calibre vessels can lead to rapid and substantial blood accumulation, which may require additional surgical techniques, such as suture ligation or electrocautery, to control bleeding. This further complicates the surgery, leading to increased operative time and potentially higher blood loss. The statistical confirmation of this difference underscores the critical importance of vascular anatomy in hepatic surgeries. Surgeons must be particularly cautious when operating near large veins, as even slight disruptions in these areas can lead to significant bleeding, making vascular control and hemostatic measures crucial in minimizing blood loss during such procedures.

Another prominent topic involves the PM. The PM is typically utilized to restrict blood inflow to the liver by occluding the hepatic artery and portal vein, with the aim of reducing haemorrhage during parenchymal transection. However, the data suggest that procedures employing PM can paradoxically exhibit higher recorded blood loss. One way of explaining this phenomenon is that the presence of the manoeuvre often signals a more challenging case in the first place, potentially marked by an extensive or highly vascularized lesion. It may also point to situations in which the surgeon anticipates more bleeding and is willing to tolerate intermittent or continuous periods of vascular occlusion to facilitate careful tumour resection

[35, 36]. As illustrated in Table 3, the difference in operating time between cases that use PM and those that do not may follow a similar pattern if controlling the inflow demands repeated clamp cycles. Longer clamp times may reduce instantaneous blood loss at specific intervals, such as during phases of parenchymal transection or when addressing particularly vascular regions of the tumour, but the net total can still be higher because these are inherently more difficult resections.

One of the most telling details about PM usage appears when comparing average bleeding volumes in operations where PM was applied versus those in which the manoeuvre was excluded. The data highlight a statistically significant divergence: the mean blood loss difference is 76.82 millilitres, confirmed by the t-test. Such results might arise from a variety of converging factors. In certain resections, PM is applied intermittently, allowing short bursts of hepatic inflow to minimize ischemic risk to the liver. Each release, however, may enable partial reperfusion of the dissected tissue bed and lead to transient spikes in bleeding. Alternatively, the necessity of PM in itself could reflect the intention to resect a lesion that is more complex in its vascular composition, reinforcing the notion that the manoeuvre is a marker for heightened surgical difficulty rather than a direct cause of higher bleeding [37, 38]. Still, these figures raise the question: if PM is meant to reduce blood loss, why does the group employing it exhibit greater net bleeding? One hypothesis is that surgeon's resort to it only after initial attempts at controlling haemorrhage prove insufficient. In these instances, the resection might already be in a more advanced or more complicated phase. Another possibility is that the presence of confounding variables – such as larger tumours or adjacency to vital vascular structures – concentrates in the group using PM, making it challenging to attribute the higher blood loss purely to the manoeuvre's effect.

Further insights emerge upon examining how the size of the haemangioma correlates with intraoperative bleeding. Larger tumours are frequently expected to have more robust vascular networks and a broader surface area for potential oozing or arterial bleeding once resected. A haemangioma, being a vascular lesion by definition, can harbour multiple channels that might haemorrhage when incised. Table 5 presents the correlation between tumour size and blood loss during surgery. It shows the Pearson correlation coefficient, significance value, and the sample size, indicating the

relationship between the size of the first haemangioma and the total blood loss recorded during surgery.

Table 5 shows a moderate positive correlation (0.333) between the size of the first haemangioma and blood loss during surgery, which is statistically significant ($p = 0.001$). This implies that, on average, larger haemangiomas are associated with greater blood loss during surgical procedures. Although correlations do not prove causality, this consistent relationship suggests that increasing tumour size may make achieving definitive haemostasis more challenging, requiring more extensive surgical intervention, longer operative times, and greater hemostatic control. This finding underscores the importance of considering tumour size when planning surgical approaches, as larger tumours might require more complex techniques to manage blood loss effectively.

The Pearson correlation of 0.333 between tumour size and blood loss is considered a moderate positive correlation. This means that as the size of the haemangioma increases, blood loss tends to increase as well, but the relationship is not extremely strong. To better understand the strength of this correlation, it can calculate the coefficient of determination (r^2), which represents the proportion of the variance in blood loss

explained by tumour size. The r^2 value is simply the square of the Pearson correlation coefficient:

$$r^2 = (0.333)^2 = 0.111 \quad (1)$$

This means that tumour size explains approximately 11.1% of the variance in blood loss during surgery. While this indicates a statistically significant relationship, it also suggests that other factors, not captured by tumour size alone, contribute to the remaining 88.9% of variance in blood loss.

Table 6 presents the regression analysis results that quantify the relationship between tumour size and blood loss. The unstandardized coefficients indicate that each additional centimetre in the size of the first haemangioma corresponds to an increase of 3.744 millilitres of blood loss. The table also provides information on the standard error, t-statistic, and significance level for these coefficients.

Table 6 shows the results of the regression analysis, which reveals a statistically significant relationship between the size of the first haemangioma and intraoperative blood loss. The unstandardized regression coefficient for tumour size is 3.744, meaning that for every additional centimetre in tumour diameter, there is an associated increase of 3.744 millilitres in

Table 5: Correlation between Tumour Size and Blood Loss

Correlations			
		Blood loss (ml)	Size first haemangioma
Blood loss (ml)	Pearson Correlation	1	0.333*
	Sig. (2-tailed)		0.001
	N	101	101
Size first haemangioma	Pearson Correlation	0.333*	1
	Sig. (2-tailed)	0.001	
	N	101	101

Note: correlation is significant at the 0.01 level (2-tailed); The asterisk (*) indicates that the correlation between tumour size and blood loss is statistically significant ($p = 0.001$), meaning that larger haemangiomas are significantly associated with greater blood loss during surgery.

Source: compiled by authors.

Table 6: Regression Analysis Coefficients between Tumour Size and Bleeding

Model	Coefficients ^a						
	Unstandardized coefficients		Standardized coefficients	t	Sig.	95.0% confidence interval for b	
	B	Std. Error	Beta			Lower bound	Upper bound
(Constant)	129.960	15.584		8.339	0.000	99.037	160.883
Size first haemangioma cm	3.744	1.124	0.317	3.330	0.001	1.513	5.975

Note: dependent variable – blood loss (ml); The asterisk (*) indicates that the regression coefficient for tumour size is statistically significant ($p = 0.001$), meaning that each additional centimetre of tumour size is associated with an increase of 3.744 millilitres of blood loss.

Source: compiled by authors.

blood loss ($p = 0.001$). While the increase of 3.744 millilitres may seem small on its own, this effect compounds significantly in larger tumours, particularly when the tumour exceeds 10 centimetres in diameter.

The cumulative effect of blood loss becomes substantial as tumour size increases, potentially requiring more extensive surgical techniques. Larger tumours necessitate more complex resections that involve more parenchymal transection and exposure of additional blood vessels, which can increase the risk of bleeding. Furthermore, the increased size may complicate surgical manipulation, extending the time needed to ensure proper hemostasis. This data underscores the importance of tumour size in preoperative planning, as larger lesions present a greater risk of blood loss and may require additional strategies to control bleeding effectively.

Regarding the second tumour, the data show no equivalent degree of association with bleeding. This discrepancy might signify that lesion-specific anatomical features of the first tumour – whether due to a unique location or a more vascular composition – drive the primary correlation. Alternatively, the second tumour might often be smaller, leading to less haemorrhage, or located in a region of the liver that is comparatively simpler to isolate and resect [39, 40]. Another relevant angle is that surgeons possibly plan resections around the largest and most problematic lesion, rendering the second tumour comparatively trivial to remove, thus negating the size-based correlation for that tumour.

Table 7 presents the correlation between the size of the first haemangioma and the duration of the PM during surgery. The table shows the Pearson correlation coefficient and significance value, indicating the strength and statistical significance of the

relationship between tumour size and the duration of PM.

Table 7 reveals a moderate positive correlation (0.332) between the size of the first haemangioma and the duration of the PM, with a statistically significant p -value of 0.048. This indicates that larger haemangiomas are associated with longer PM durations. The increased size of the tumour likely leads to more complex surgical procedures, requiring longer periods of inflow occlusion to manage blood loss effectively. Larger tumours often involve multiple steps, such as parenchymal transection and haemostatic checks, which may necessitate repeated PM intervals. Furthermore, the surgeon may opt to keep the clamp in place for longer periods if ongoing bleeding or oozing is observed in deeper tissue layers, further extending the duration of the PM. This correlation highlights the critical role of tumour size in determining the length of time required for effective vascular control, which is essential for managing bleeding during complex liver resections. Therefore, the data suggests that larger tumours may require more time under PM, increasing the surgical complexity and potential risks associated with the procedure.

Table 8 presents the results of the regression analysis, showing the relationship between tumour size and the duration of the PM. The table includes unstandardized coefficients, standard errors, t -statistics, significance values, and the 95% confidence intervals for the regression coefficients, helping to quantify how tumour size influences the time spent under PM.

Table 8 demonstrates a statistically significant relationship between the size of the first haemangioma and the duration of the PM, with a regression coefficient of 8.343. This means that for each additional

Table 7: Correlation between Tumour Size and PM

Correlations			
		Size first haemangioma cm	Pringle min.
Size first haemangioma cm	Pearson Correlation	1	0.332 [*]
	Sig. (2-tailed)		0.048
	N	101	36
Pringle min.	Pearson Correlation	0.332 [*]	1
	Sig. (2-tailed)	0.048	
	N	36	36

Note: dependent variable – Pringle min.; correlation is significant at the 0.05 level (2-tailed); The asterisk (*) indicates that the correlation between tumour size and the duration of the Pringle maneuver is statistically significant at the 0.05 level ($p = 0.048$).

Source: compiled by authors.

Table 8: Regression Analysis Coefficients between Tumour Size and Time with PM

Model	Coefficients*						
	Unstandardized coefficients		Standardized coefficients	t	Sig.	95.0% confidence interval for B	
	B	Std. error	Beta			Lower bound	Upper bound
Constant	4.362	10.278		0.424	0.674	-16.525	25.248
Size first haemangioma cm	8.343	3.627	0.367	2.300	0.028	0.971	15.715

Note: dependent variable – Pringle min.: The asterisk (*) indicates statistical significance, specifically that the size of the first haemangioma significantly influences the time spent using the Pringle maneuver ($p = 0.028$).

Source: compiled by author.

centimetre in tumour size, the time spent under PM increases by approximately 8.343 minutes ($p = 0.028$).

This result suggests that larger tumours require more extensive dissection and a more comprehensive approach to vascular control, as they often contain a greater number of blood-filled channels. The time spent occluding the blood vessels to control bleeding during surgery increases. Preoperative planning for larger tumours may anticipate longer resections, prompting the surgical team to keep the clamp in place longer to avoid frequent fluctuations in hepatic perfusion, which can complicate the procedure. The data underscores the importance of tumour size in determining the duration of PM, which directly impacts the complexity and time required for the surgical procedure. Larger haemangiomas present additional challenges in terms of blood loss management, and as such, require careful surgical planning and extended duration of vascular occlusion [41].

An interesting dimension to these observations is the apparent absence of a parallel size relationship for the second tumour, both in terms of blood loss and PM time. One possibility is that when multiple haemangiomas are present, the focus often rests on resecting the largest lesion under the best possible conditions. That emphasis might overshadow the effect of smaller or more peripheral lesions, either because their vascular supply is less robust or because their removal occurs concurrently in a region of the liver that has already been partially devascularized by the main resection steps. In some scenarios, the second tumour might be so small that it barely impacts the operative plan. Conversely, if it is only slightly smaller but located in a more accessible hepatic segment, then it might not necessitate lengthy Pringle intervals or result in sizable additional blood loss. These data collectively suggest that the size of the first haemangioma exerts the more prominent influence, whereas the second tumour can

be less determinative unless it shares comparable characteristics.

None of these correlations or differences in mean blood loss can be viewed in isolation. Several confounders could complicate the interpretation of the raw figures. However, the data consistently point toward three major factors that shape the haemostatic challenge: adjacency to large vessels, usage of the PM, and tumour diameter. The first factor likely amplifies the difficulty of controlling major branches and imposing effective haemostasis, the second signals a more labour-intensive or inherently haemorrhage-prone procedure, and the third adds a dimension of size-driven vascularization that can markedly increase total bleeding and possibly demand prolonged inflow occlusion. Such trends suggest that surgeons might need to incorporate these considerations into their preoperative planning. More time or specialized equipment may be allocated to resections of bigger haemangiomas, particularly if they lie close to significant veins. The data also implicitly indicate that if a lesion is recognized to be large, the team might anticipate prolonged PM intervals, which could in turn inform anaesthesia management and fluid replacement protocols.

Another aspect relates to the hemodynamic changes that accompany each step of PM usage. A large tumour, especially one pressing against or involving important vascular structures, may require repeated toggling of hepatic inflow control. This toggling can translate into a cyclical process: blood flow is halted, tissue is dissected, bleeders are addressed, and then flow is briefly reinstated to check for persistent bleeding or to sustain hepatic viability. Each cycle could incrementally elevate total blood loss if the tumour's vascular architecture is sufficiently extensive. At the same time, maintaining the occlusion for longer stretches, as supported by the regression analysis, might reduce acute bleeding surges but still yield a

higher net loss because the underlying tumour remains complex to resect. Larger lesions, therefore, rarely permit an expeditious single pass. Instead, they present multiple dissection planes that must be methodically cleared and sealed.

Data highlight the interplay between tumour proximity to significant venous structures, the necessity or duration of the PM, and the tumour's size. Proximity leads to challenging dissections and a quantifiable spike in bleeding, as confirmed by both the group statistics and t-tests. The PM, while helpful in theory, often correlates with higher total bleeding volumes, possibly because it is employed chiefly in more difficult or vascular cases. Larger haemangiomas link to increased bleeding and more extensive PM intervals, reinforcing the idea that these lesions are proportionally harder to manage. Although the second tumour's size and relationship to PM usage do not show the same statistical strength, the presence of an additional lesion could still contribute in smaller ways to operative complexity, depending on location and vascular supply. Each of these observations stands on the premise that certain anatomic and technique-related factors can compound, leading to variable but measurable shifts in operative blood loss.

DISCUSSION

Certain findings indicate that haemangioma location exerts a marked influence on intraoperative blood loss. Si S, *et al.* [42] compared 140 laparoscopic resections by subdividing patients into two groups: "massive" (≥ 800 ml) and "minor" (< 800 ml) blood loss. The "massive" group accounted for 24 patients, and the analysis pinpointed Couinaud segments I, IVa, VII, and VIII as significant risk areas. Those anatomic regions are often accompanied by more complex vascular branches and limited surgical angles, making it difficult to achieve rapid haemostasis. In the current analysis, the overall intraoperative bleeding for most haemangioma localizations remains at a moderate level, without showing the steep increases or distinct distribution patterns reported elsewhere. The data here do not align with authors, who described substantially elevated blood loss in certain hepatic segments characterized by extensive vascular complexity. In that earlier report, bleeding volumes rose sharply, surpassing thresholds not observed in the present sample. By contrast, the figures outlined here indicate more modest differences across various tumour localizations, even when multiple lobes or major venous structures are involved. This discrepancy could

be attributable to divergent methodologies, alternate patient selection criteria, or distinct operative protocols, all of which might influence the net amount of haemorrhage. It may also reflect variations in the proportion of exceptionally large lesions or emergent cases, factors that tend to inflate intraoperative blood loss. Direct numerical comparisons with Si S, *et al.* [42] become problematic, since that investigation focuses on a separate set of clinical circumstances. The outcomes shown here do not replicate the same high-volume bleeding scenarios, suggesting that the hemodynamic risks described in prior work may not be fully applicable to this dataset's scope or surgical approach.

Another study, Tan H, *et al.* [43], focused on enucleation for right-sided haemangiomas and found median estimated blood losses of 500 ml (interquartile range 200-975 ml) in a laparoscopic group and 500 ml (300-925 ml) in an open group. Despite near-identical median values, the authors reported more frequent usage of the PM in the laparoscopic subset (100%) than in the open subset (67.6%). The difference in manoeuvre deployment may have masked underlying locational risks, leading to comparable bleeding volumes. In the present series, 35% of procedures employ the PM, and blood loss is notably higher (223.714 ml vs. 146.894 ml) when it is used. One explanation is that the manoeuvre is typically selected for difficult cases – particularly large or high-risk lesions – and thus the final volumes reflect higher baseline complexity, even though the measure is intended to reduce active haemorrhage.

A separate cohort from Xie QS, *et al.* [44] analysed 152 patients with giant haemangiomas (≥ 10 cm). The mean estimated blood loss across the full sample was 343 ml, with recorded ranges from 10 to 1,200 ml. Stratified by surgical approach, the open group averaged 319 ± 245 ml, and the laparoscopic group averaged 282 ± 190 ml, indicating a moderate difference in favour of minimally invasive procedures. However, giant tumours exceeding 15 cm were more common in that study, and the authors prioritized advanced imaging (including 3D reconstruction) to manage anatomically complex cases. In the data presented here, tumour size and location operate in tandem: bilateral or large right-sided lesions often require extended dissection, which correlates with higher mean blood loss – between roughly 189 and 249 ml in localized groups, but occasionally spiking toward 400 ml in difficult resections. Authors did not dissect their results in relation to specific lobar segments or venous

adjacency. Nonetheless, their range of up to 1.200 ml underscores the degree to which large dimensions and challenging vascular architecture can magnify bleeding, mirroring the upper-limit findings of 400 ml in the current analysis for tumours smaller than those described as “extremely giant.”

Multiple reports on liver haemangioma resections have documented considerably higher intraoperative blood loss than the volumes reflected in the current dataset. Farhat W, *et al.* [45], describing a decade of experience in managing giant hepatic haemangiomas, recorded a median blood loss of approximately 870 ml in 12 patients. The individuals in that cohort often presented with extremely large lesions or episodes of rupture that likely exacerbated intraoperative haemorrhage. The authors emphasized that bilobar involvement and haemangioma rupture frequently trigger transfusion needs and protracted operative courses. The median hospital stay was about 5.3 days, and one postoperative fatality was noted, attributed to a pulmonary embolism. Despite the small sample size, those data illustrate that more extensive or emergent presentations of liver haemangiomas can correlate with more pronounced blood loss, a pattern widely observed in other cohorts focusing on similarly large tumours.

Hu M, *et al.* [46] compared three surgical modalities – robotic, laparoscopic, and open approaches – in patients with haemangioma as exceeding 10 cm. In that particular series, the documented mean blood loss values were roughly 319.5 ml with robotic operations, 476.9 ml with laparoscopic resections, and 628.0 ml during open procedures. The variation in bleeding volumes was attributed to different methods of vascular control, distinct learning curves for minimally invasive surgery, and the broader complexity associated with giant lesions. The authors highlighted that robotic and laparoscopic strategies appeared to reduce both transfusion rates and operative trauma in certain subsets, yet the open group continued to show relatively higher cumulative blood loss. Although the data from Hu M, *et al.* remain representative of giant haemangiomas above 10 cm, the lower average volumes noted in robotic or laparoscopic resections still surpass those captured in the present analysis for the majority of tumour localizations.

Additional insights emerge from the work of Oldhafer KJ, *et al.* [47], which described situations in which blood loss commonly exceeded 400 ml, especially if the haemangioma occupied awkward anatomic sectors, involved the hepatic dome region, or

overlapped major vascular structures near the retrohepatic vena cava. That series further suggests that the degree of hepatic mobilization, the presence of dense adhesions, or local inflammatory processes could each heighten intraoperative bleeding risk. Complex cases with partial thrombosis, compression of vital veins, or infiltration around portal pedicles were repeatedly cited as key contributors to large haemorrhagic volumes.

Several factors might account for the apparent discrepancy. One possibility is that the current group includes fewer ruptured lesions, giant tumours, or bilobar cases with advanced disease, thus reducing the likelihood of extensive vascular engagement. Another potential explanation involves the standardization of perioperative management and the use of systematic vascular control manoeuvres, such as intermittent Pringle clamping or meticulous inflow occlusion, which can curtail bleeding. In some published cohorts, immediate surgery for emergent rupture or for extremely large tumours was more frequent, resulting in inflated median and mean values for intraoperative haemorrhage. Institution-specific protocols, surgeon expertise, and selection criteria for operative intervention differ among centres, making direct numerical comparisons inherently challenging. Differences in tumour size thresholds provide an additional source of variability. The net result is that many of the published figures surpass those recorded here, underscoring the importance of patient selection, tumour characteristics, and surgical planning in determining actual blood loss levels.

CONCLUSIONS

This study successfully addressed the existing gap in hepatic haemangioma research by analyzing a diverse, multicentre patient cohort, including tumours of various sizes, locations, and surgical techniques. The findings provided a direct comparison of factors influencing surgical risk, refining preoperative risk assessment and optimizing intraoperative strategies. By identifying key determinants of blood loss and surgical complexity, the study has contributed valuable insights to improve operative planning and patient outcomes. These results confirm that tumour size, location, and vascular characteristics are critical factors in determining intraoperative blood loss and surgical difficulty, highlighting the importance of tailored surgical approaches to enhance patient care.

This study provides valuable insights into the factors influencing intraoperative blood loss during liver

resections for hepatic haemangiomas. Our findings underscore the significant role of tumour localization, size, and proximity to major venous structures in determining blood loss during surgery. Bilateral haemangiomas were found to be associated with the highest mean blood loss (249.167 ml), followed by right-sided lesions (189.286 ml), while left-sided tumours exhibited the lowest mean blood loss (149.255 ml). Statistically significant differences were observed between the various localisation groups ($F = 4.973$; $p = 0.003$), with bilateral lesions posing the greatest challenge in terms of blood loss management.

Larger haemangiomas also demonstrated a moderate positive correlation ($r = 0.333$; $p = 0.001$) with blood loss, suggesting that increasing tumour size is linked to a higher volume of bleeding during resection. Regression analysis revealed that each additional centimetre of tumour size is associated with an increase of 3.744 millilitres in blood loss, highlighting the importance of tumour size in surgical planning. The study also highlighted the impact of the Pringle maneuver on intraoperative blood loss, with larger tumours necessitating longer durations of PM, leading to an average increase of 8.343 minutes for each additional centimetre in tumour size ($p = 0.028$). This extended PM duration, combined with the complex vascular anatomy of larger haemangiomas, underscores the need for more precise and prolonged vascular control in these cases.

Haemangiomas located near large venous vessels were associated with higher blood loss and longer operating times. Procedures near these major structures resulted in a mean blood loss of 228.889 ml compared to 153.311 ml for lesions located away from large veins, with a statistically significant mean difference of 75.58 ml ($p = 0.000$). The results indicate that right-sided and bilateral haemangiomas require more complex surgical strategies, involving optimized vascular control, early identification and ligation of feeding vessels, and extended PM use. Surgeons should anticipate these challenges when planning for resections of larger or more complex tumours, particularly those located in regions with intricate vascular networks.

Despite the value of these observations for surgical stratification and patient counselling, certain limitations are acknowledged. Heterogeneity in tumour size, operative technique, and patient comorbidities may influence the final bleeding volumes, complicating direct comparisons between subgroups. The absence of universal criteria for defining massive blood loss also

reduces the capacity to benchmark these findings against external cohorts.

Future investigations may benefit from large, multicentre collaborations designed to capture diverse patient populations and operative nuances. Standardized definitions of excessive bleeding, combined with emerging technologies (e.g., real-time fluorescence imaging or perfusion mapping), could further refine the assessment of risk in various anatomic segments. Refined outcome measures, tied to patient-reported experiences and long-term follow-up, may enhance the understanding of how lesion size and hepatic segment location interact with broader surgical trends and evolving vascular management techniques.

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