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Article

Impact of ROTEM® Use in Oncology Patients Undergoing Cancer Surgery: A Retrospective Historical Cohort Study

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Simple Summary

Major cancer surgery often causes heavy bleeding, and standard laboratory tests are too slow and incomplete to guide which blood products a patient needs. A bedside test called rotational thromboelastometry (ROTEM) shows in real time how a blood clot forms and may help clinicians give only the products that are truly needed. We reviewed the records of 137 adults who underwent planned cancer surgery at a specialized cancer center in Chile and compared patients whose bleeding was managed with ROTEM with those managed conventionally. Overall, the use of blood products was similar in both groups. However, in the most complex operations, patients managed with ROTEM were less likely to receive fresh frozen plasma. These findings suggest that ROTEM may support a more targeted use of blood products, although larger prospective studies are needed.

Abstract

Background/Objectives: Major oncologic surgery is frequently associated with substantial blood loss and perioperative coagulopathy. Conventional coagulation tests provide limited and delayed assessment during active bleeding, whereas rotational thromboelastometry (ROTEM) enables real-time evaluation of clot formation. This study evaluated the transfusion and clinical impact of ROTEM guided hemostatic management in major oncologic surgery. **Methods:** This retrospective historical cohort study included 137 adults undergoing elective oncologic surgery at a specialized cancer center between January 2020 and December 2023. Patients with intraoperative bleeding received either conventional management (n = 90) or ROTEM guided management (n = 47). Demographic and clinical characteristics, surgical risk, estimated blood loss, transfusion requirements, vasoactive drug use, and hospital length of stay were compared. A predefined subgroup of 79 patients undergoing complex oncologic procedures was also analyzed. **Results:** Baseline characteristics were comparable between groups. Overall, 87.6% of procedures were high risk, and 73.7% of patients had blood loss >1000 mL. Transfusion requirements did not differ significantly in the overall cohort. In complex oncologic surgery, ROTEM guided management was associated with fewer patients receiving fresh frozen plasma than conventional management (24.2% vs. 54.3%, $p = 0.011$). Red blood cell transfusion was numerically lower with ROTEM, while vasoactive drug use and hospital length of stay did not differ significantly. **Conclusions:** ROTEM guided management was associated with reduced fresh frozen plasma exposure in complex oncologic surgery, supporting a more targeted transfusion strategy. Prospective studies are needed to confirm its effects on clinical outcomes.

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Keywords: rotational thromboelastometry; ROTEM; viscoelastic testing; oncologic surgery; perioperative coagulopathy; blood transfusion; fresh frozen plasma; patient blood management

1. Introduction

Surgery remains the primary curative pillar in the treatment of major solid tumors [1]. However, such interventions are often complex and carry a high risk of acute, massive hemorrhage (a major cause of morbidity and mortality) which can lead to hemostatic disturbances and perioperative coagulopathy [1–3]. Massive transfusion protocols developed for trauma settings should not be directly applied to oncological cases, given the specific characteristics of cancer-associated coagulopathy [4]. This coagulopathy manifests as a dynamic hemostatic spectrum, driven by the tumor-mediated release of tissue factor (TF), procoagulant microparticles, and activating mucins, alongside the suppression of fibrinolysis, a process mediated by the overexpression of PAI-1 [5,6]. This dysregulation creates a baseline prothrombotic state that coexists with the risk of catastrophic bleeding, exacerbated by coagulation factor consumption and hemodilution during surgery [1,6].

For decades, perioperative hemostatic assessment has relied on conventional plasma-based laboratory tests (CCTs), including prothrombin time (PT), international normalized ratio (INR), activated partial thromboplastin time (aPTT), and platelet count [1,7,8]. Scientific evidence, however, highlights several limitations of these tests. Because they are performed on platelet-poor plasma, they fail to evaluate cellular interactions, platelet function, or the fibrinogen network as they exist in whole blood; rather, they assess only a fraction of the coagulation components. Furthermore, the time required to obtain results (45–60 minutes) precludes rapid clinical decision-making during active surgical bleeding [1,8,9]. Additionally, the INR tends to overestimate the degree of coagulopathy in stable surgical patients and those undergoing major hepatic resections [10,11]. Finally, conventional tests fail to detect the hypercoagulable states and hypofibrinolysis characteristic of cancer patients [1,8].

Rotational thromboelastometry (ROTEM) dynamically analyzes the viscoelastic properties of whole blood, from thrombin activation through to maximum clot firmness and subsequent clot lysis [12–14]. It offers a shorter turnaround time and assesses the final outcome of hemostasis by accounting for the interaction of most coagulation factors. Furthermore, it enables the identification of specific deficiencies that may require supplementation to achieve adequate coagulation. Its use paves the way for a goal-directed transfusion strategy that is more precise, without delaying clinical management in critical situations [13–16].

The objective of this study is to analyze the clinical and transfusion-related impact of implementing a ROTEM guided protocol in patients undergoing high-risk major oncological surgery [1,9]. It is hypothesized that the use of ROTEM will allow for the identification of this specific hemostatic profile and guide a more restrictive transfusion strategy, resulting in a lower requirement for hemostatic products during intraoperative bleeding compared to strategies based on conventional tests or those described in other surgical populations [1,15].

2. Materials and Methods

2.1. Study Design and Population

This was a retrospective, observational, historical cohort study conducted at Fundación Arturo López Pérez (FALP) in Santiago, Chile. We evaluated 137 adult patients (>18 years) who underwent elective oncologic surgery between 1 January 2020 and 31 December 2023. Patients with congenital coagulopathies or with active direct oral anticoagulant therapy that had not been discontinued according to the institutional protocol were excluded. Eligible patients were identified from electronic health records with support from the institutional Data Unit, specifically by screening anesthesia reports.

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2.2. Hemostatic Management Groups

During the study period, 263 patients who experienced intraoperative bleeding were identified and evaluated for eligibility. Initially, 178 patients fell within the period prior to the implementation of ROTEM® and received conventional hemostatic management, while 85 were treated after its implementation using a transfusion strategy guided by viscoelastic testing. Following the application of inclusion and exclusion criteria, the final cohort consisted of 137 patients: 90 in the conventional management group (without ROTEM®) and 47 in the group receiving ROTEM®-guided hemostatic therapy. Rotational thromboelastometry was performed using a fully automated ROTEM® sigma system (software version 5.3.0, Tem Innovations GmbH, Munich, Germany; a Werfen company). Citrated whole-blood samples were analyzed using either the ROTEM® sigma complete cartridge (EXTEM C, INTEM C, FIBTEM C, and APTEM C).

A subgroup of 79 patients who underwent complex oncologic surgery, defined as cytoreductive digestive surgery, hepatectomy, wide sarcoma resection, and pelvic exenteration, was analyzed separately. ROTEM was used in 33 of these patients.

2.3. Variables

The following data were recorded: demographic characteristics (age and sex), prior neoadjuvant therapy (chemotherapy, radiotherapy, and immunotherapy), type and specialty of surgery, surgical risk category, estimated blood loss (mL), effective length of hospital stay (days), and number of units of blood components transfused.

2.4. Statistical Analysis

Quantitative variables were described using summary measures (mean and standard deviation (SD); median, minimum, and maximum), and categorical variables were described using absolute and relative (percentage) frequencies. After assessing normality with Shapiro–Wilk test, quantitative variables were compared between patients with and without ROTEM using the Wilcoxon-Mann-Whitney test. Categorical variables were compared using Fisher's exact test. A significance level of 0.05 was considered, and all analyses were performed using R software, version 4.3.1.

2.5. Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was reviewed and approved by the Scientific Ethics Committee (Comité de Ética Científico) of Fundación Arturo López Pérez on April, 3rd, 2024 (Clinical Research Protocol No. 2024-422-ANE-SIN-INT).

3. Results

3.1. Patient Characteristics

Table 1 describes the demographic and clinical characteristics of the 137 patients included in the study and compares them according to the use of ROTEM. The mean age was 58.5 years, and 50.4% of the patients were female. Overall, 54.7% of the patients had not received oncologic treatment, and chemotherapy, alone or combined with radiotherapy, was the most frequent treatment (34.3%). Digestive surgeries were the most frequent procedures, the vast majority were high-risk surgeries (87.6%), and 73.7% of the patients had blood loss greater than 1000 mL. None of the patients had a history of cardiovascular disease. No significant differences between the two groups were found in any of the characteristics analyzed (Table 1).

Table 1. Demographic and clinical characteristics of the patients according to the use of rotational thromboelastometry (ROTEM).

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	Without ROTEM (*n* = 90)	With ROTEM (*n* = 47)	Total (*n* = 137)	*p* *
Age (years)				
Mean (SD)	57.6 (14.5)	60.3 (11.7)	58.5 (13.6)	0.355
Median [Min., Max.]	60.0 [16.0, 83.0]	65.0 [35.0, 77.0]	61.0 [16.0, 83.0]	
Sex				
Female	43 (47.8%)	26 (55.3%)	69 (50.4%)	0.473
Male	47 (52.2%)	21 (44.7%)	68 (49.6%)	
Oncologic treatment				
Chemotherapy	16 (17.8%)	12 (25.5%)	28 (20.4%)	
Radiotherapy	4 (4.4%)	1 (2.1%)	5 (3.6%)	
Immunotherapy	1 (1.1%)	2 (4.3%)	3 (2.2%)	0.516
Chemotherapy + radiotherapy	13 (14.4%)	6 (12.8%)	19 (13.9%)	
None	52 (57.8%)	23 (48.9%)	75 (54.7%)	
Missing data	4 (4.4%)	3 (6.4%)	7 (5.1%)	
Type of surgery				
Head and neck	8 (8.9%)	1 (2.1%)	9 (6.6%)	
Neurological	6 (6.7%)	2 (4.3%)	8 (5.8%)	
Thoracic	5 (5.6%)	2 (4.3%)	7 (5.1%)	
Digestive	35 (38.9%)	28 (59.6%)	63 (46.0%)	
Orthopedics and traumatology	11 (12.2%)	4 (8.5%)	15 (10.9%)	
Gynecology	7 (7.8%)	3 (6.4%)	10 (7.3%)	0.321
Urology	15 (16.7%)	5 (10.6%)	20 (14.6%)	
Free flap	2 (2.2%)	0 (0%)	2 (2.2%)	
Muscle flaps	1 (1.1%)	0 (0%)	1 (1.1%)	
Exenteration	0 (0%)	1 (2.1%)	1 (0.7%)	
Vascular	0 (0%)	1 (2.1%)	1 (0.7%)	
Surgical risk				
Low	1 (1.1%)	0 (0%)	1 (0.7%)	
Moderate	13 (14.4%)	3 (6.4%)	16 (11.7%)	0.311
High	76 (84.4%)	44 (93.6%)	120 (87.6%)	
Intraoperative blood loss				
<500 mL	13 (14.4%)	6 (12.8%)	19 (13.9%)	
500–1000 mL	11 (12.2%)	6 (12.8%)	17 (12.4%)	1.000
>1000 mL	66 (73.3%)	35 (74.5%)	101 (73.7%)	

ROTEM, rotational thromboelastometry; SD, standard deviation; Min., minimum; Max., maximum. *Quantitative variables: Wilcoxon–Mann–Whitney test; categorical variables: Fisher's exact test.

3.2. Transfusion Requirements in the Overall Cohort

Table 2 shows the consumption of blood products in the whole cohort and according to ROTEM use, including the requirements for red blood cell (RBC) transfusion and for the remaining blood products (fresh frozen plasma (FFP), cryoprecipitate, platelet concentrate, prothrombin complex concentrate, and fibrinogen concentrate). Although some differences were observed between patients according to ROTEM use, none of them were statistically significant.

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Table 2. Consumption of blood products according to ROTEM use.

	Without ROTEM (*n* = 90)	With ROTEM (*n* = 47)	Total (*n* = 137)	*p* *
Red blood cells	87 (96.7%)	43 (91.5%)	130 (94.9%)	0.232
Cryoprecipitate	18 (20.0%)	14 (29.8%)	32 (23.4%)	0.209
Fresh frozen plasma	34 (37.8%)	12 (25.5%)	46 (33.6%)	0.184
Platelet concentrate	11 (12.2%)	8 (17.0%)	19 (13.9%)	0.446
Prothrombin complex concentrate	0 (0%)	2 (4.3%)	2 (1.5%)	0.116
Fibrinogen concentrate	1 (1.1%)	1 (2.1%)	2 (1.5%)	1.000

*p-values were obtained using Fisher's exact test.

3.3. Complex Oncologic Surgery

Of all the patients studied, 79 underwent complex oncologic surgery, including cytoreductive digestive surgery, hepatectomy, wide sarcoma resection, and pelvic exenteration; ROTEM was used in 33 of them. **Figure 1** shows the percentage consumption of the different blood products in all patients who underwent complex surgery and according to ROTEM use. RBCs were the most frequently transfused product, whereas the remaining blood products were required less often. When comparing ROTEM use, differences were observed only in FFP consumption, with a significantly lower percentage in the ROTEM group (24.2% vs. 54.3%, p = 0.011).

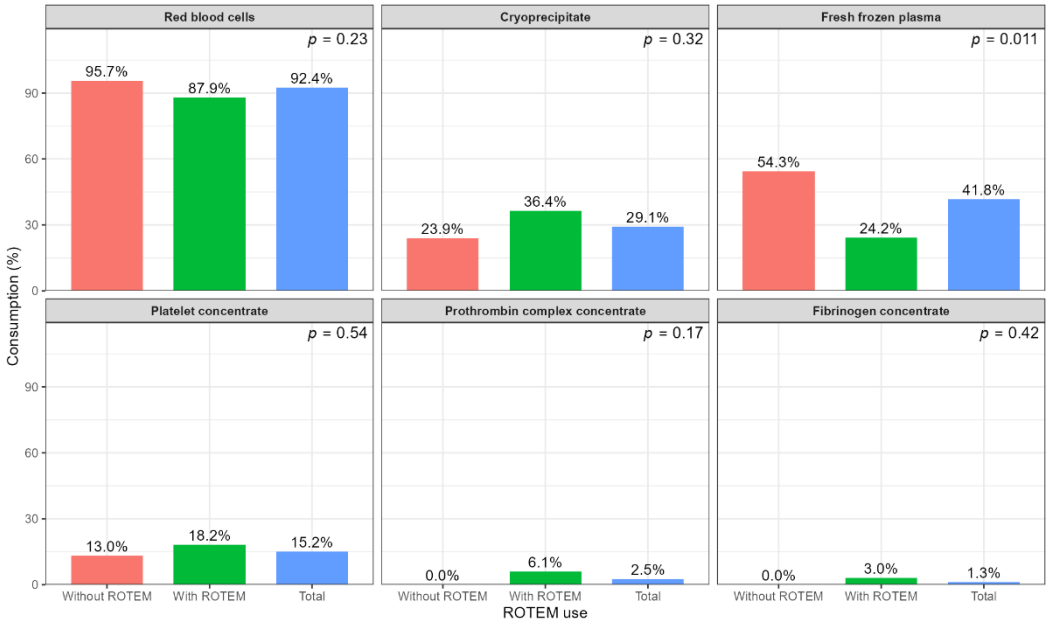

Figure 1. *Percentage of blood product consumption in patients undergoing complex oncologic surgery (n = 79), according to ROTEM use.* *p-values were obtained using Fisher's exact test.

3.4. Length of Hospital Stay

Table 3 compares the scheduled and effective length of hospital stay according to ROTEM use in all patients; no significant differences were found.

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Table 3. Scheduled and effective length of hospital stay according to ROTEM use.* Wilcoxon–Mann–Whitney test.

	Without ROTEM (*n* = 90)	With ROTEM (*n* = 47)	Total (*n* = 137)	*p* *
Scheduled length of stay (days)				
Mean (SD)	7.99 (3.88)	8.76 (3.36)	8.25 (3.72)	
Median [Min., Max.]	8.00 [1.00, 18.0]	9.00 [2.00, 16.0]	8.00 [1.00, 18.0]	0.209
Missing data	1 (1.1%)	1 (2.1%)	2 (1.5%)	
Effective length of stay (days)				
Mean (SD)	14.5 (12.0)	20.7 (26.9)	16.6 (18.7)	
Median [Min., Max.]	11.0 [1.00, 69.0]	12.0 [4.00, 150]	12.0 [1.00, 150]	0.251
Missing data	1 (1.1%)	0 (0%)	1 (0.7%)	

Figure 2 shows the distribution of the scheduled and effective length of hospital stay according to ROTEM use in the 79 patients who underwent complex surgery, in whom no statistically significant differences between groups were found either.

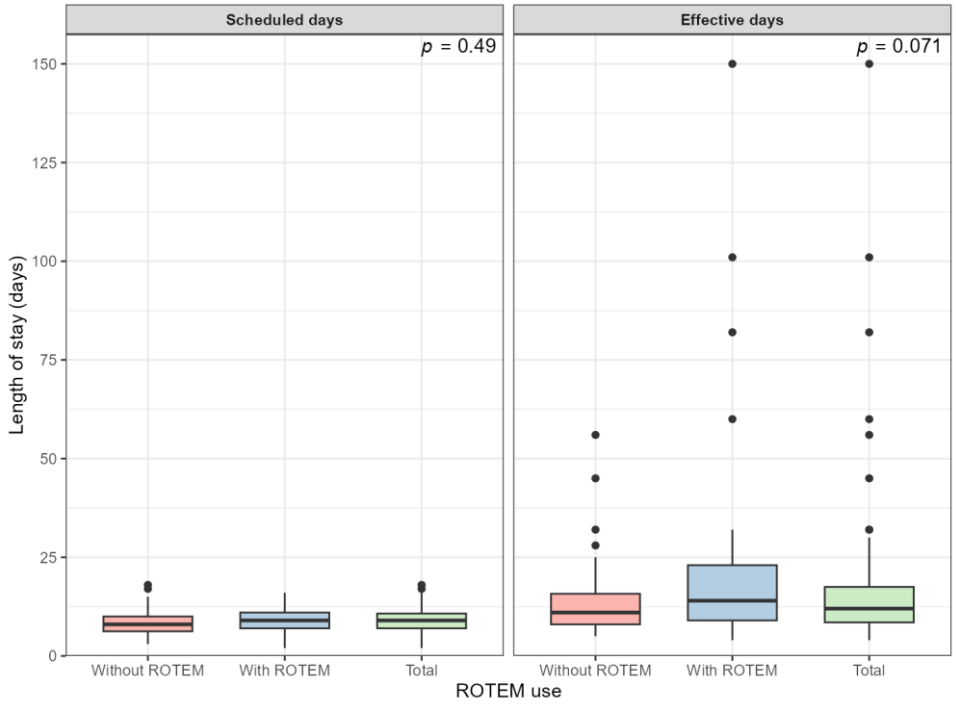

Figure 2. Distribution of the scheduled and effective length of hospital stay in patients undergoing complex oncologic surgery (*n* = 79), according to ROTEM use (No/Yes).

*p-values were obtained using the Wilcoxon–Mann–Whitney test.

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4. Discussion

The implementation of rotational thromboelastometry (ROTEM®) in major oncological surgery allows for a shift from predominantly empirical transfusion strategies toward individualized, goal-directed hemostatic therapy [10]. In our study, the use of ROTEM® was associated with reduced exposure to fresh frozen plasma in the subgroup of patients undergoing complex oncological surgeries (24.2% vs. 54.3%; p = 0.011). Furthermore, a pattern consistent with more selective administration of blood components and hemostatic agents—tailored to the specific coagulation abnormality identified was observed. These results support the integration of point of care viscoelastic testing into Patient Blood Management programs, particularly for procedures associated with significant hemorrhage that require therapeutic decisions to be made within short timeframes [10].

These findings are consistent with the meta-analysis by Wikkelso et al. and the clinical review by Erdoes et al., in which algorithms based on viscoelastic testing were associated with a reduction in the transfusion of fresh frozen plasma (RR 0.57), red blood cell concentrates (RR 0.86), and platelets (RR 0.73) [16,17]. However, most of the existing evidence originates from cardiac surgery, liver transplantation, trauma, and obstetric hemorrhage; therefore, its extrapolation to non-cardiac oncological surgery should be approached with caution.

Our results are based on the ability of viscoelastic tests to dynamically assess clot initiation, formation, firmness, and lysis. FIBTEM provides an estimate of the contribution of fibrin to clot firmness, while EXTEM CT yields information regarding the factor-dependent initiation phase of coagulation. Consequently, these tests help to differentiate between a decrease in the functional contribution of fibrinogen, a deficiency in coagulation factors, a reduction in overall clot firmness, or a pattern of hyperfibrinolysis [12,18]. This functional characterization can prevent the indiscriminate administration of plasma and facilitate the selection of the most appropriate hemostatic treatment.

Dias et al. conducted a systematic review and meta-analysis that included 20 randomized trials involving major elective surgery. Therapy guided by viscoelastic testing was associated with a reduction in the transfusion of red blood cells standardized mean difference (SMD) -0.16; 95% CI (-0.29 to -0.02), platelets SMD −0.33; 95% CI (-0.56 to -0.10), and fresh frozen plasma SMD -0.64; 95% CI (-1.01 to -0.28), as well as less blood loss and a shorter length of stay in the intensive care unit. However, no reduction was observed in reinterventions (RR 1.09; 95% CI 0.70 to 1.69), mortality, or total duration of hospitalization. A decrease in the administration of cryoprecipitate and in perioperative complications was observed exclusively in studies that used TEG; therefore, these results should not be specifically attributed to ROTEM® [19]. Furthermore, the included trials consisted predominantly of cardiac and hepatic surgeries, with very limited representation from other surgical specialties.

Relying solely on abnormalities in prothrombin time or the INR as an indication for transfusion can lead to the unnecessary administration of large volumes of fresh frozen plasma. These plasma-based tests evaluate only specific phases of fibrin generation; they do not account for the contribution of platelets or fibrinolysis, and they have a limited capacity to predict perioperative bleeding. Furthermore, plasma transfusion results in minimal correction of the INR when it is only mildly or moderately prolonged, while exposing the patient to complications such as transfusion-associated circulatory overload, acute lung injury, and allergic reactions [3,20]. In cancer patients, transfusion-related immunomodulation is a biologically plausible mechanism, although a definitive causal link between plasma transfusion and tumor recurrence has not been established.

Some reviews have reported that transfusion algorithms guided by viscoelastic tests may reduce the volume of blood loss, the administration of plasma and platelets, the need for reoperation, and certain complications, such as acute kidney injury requiring renal replacement therapy (RR 0.46) [9,16]. However, results regarding mortality and other patient-centered outcomes have not been consistent. Consequently, the primary benefit demonstrated to date appears to be related to a more selective use of blood components, while its impact on major clinical outcomes remains uncertain.

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Beyond their application in the management of bleeding, viscoelastic tests can identify patterns consistent with hypercoagulability and reduced fibrinolytic activity in cancer patients [1,3,5,21]. In a prospective study of patients with bone tumors, Tsantes et al. observed that prothrombin time (PT), activated partial thromboplastin time (aPTT), and platelet count did not show significant differences compared to a control group. In contrast, ROTEM® identified a shortening of EXTEM CT (clotting time) and CFT (clot formation time), along with an increase in A10 (clot amplitude at 10 minutes) and MCF (maximum clot firmness), findings consistent with a prothrombotic phenotype [1]. Similar results have been reported by Davies et al. in lung cancer, Toukh et al. in prostate cancer, and Hincker et al. in major non-cardiac surgery. In these studies, cancer patients exhibited shortened CT or CFT and increased A10 or MCF—parameters consistent with accelerated clot formation and greater clot firmness [7]. Conventional coagulation tests may remain within normal ranges in these patients, as they were primarily designed to detect factor deficiencies rather than to assess hypercoagulability. Nevertheless, the association between viscoelastic parameters and postoperative thromboembolic complications remains heterogeneous, depending on the type of tumor, the surgical procedure, and the threshold used to define hypercoagulability [12].

In oncological neuroanesthesia, the balance between bleeding and thrombosis is particularly significant, given the serious neurological consequences of both events and the caution with which pharmacological thromboprophylaxis is typically initiated. In the observational study by Khatri et al., conducted on patients undergoing surgery for primary brain tumors, thromboelastography revealed a tendency toward hypercoagulability, both intraoperatively and during the first 24 hours post-procedure, an alteration that was not detected by conventional tests [22]. This phenomenon may be linked to tumor-specific mechanisms, such as the expression of tissue factor and podoplanin, particularly in gliomas, as well as factors inherent to neurosurgery, including the duration of the procedure, patient immobilization, and the neuroendocrine response to surgical stress. However, the study was not designed to establish a causal relationship between these mechanisms and the observed viscoelastic changes.

Sabharwal et al. evaluated the presence of hypercoagulability in 52 patients with sarcomas, soft-tissue tumors, or bone metastases using preoperative thromboelastography. Sixty percent of the patients exhibited at least one alteration consistent with a hypercoagulable state. This pattern was more frequent in women than in men (75% vs. 46%; OR 3.5; 95% CI 1-11; $p = 0.04$) and in patients with soft-tissue tumors. Neither tumor location nor the presence of metastatic disease showed a significant association. Notably, symptomatic deep vein thrombosis occurred in 16% of patients with a hypercoagulable thromboelastography (TEG) profile, compared to 0% of those with a normal profile [23]. Although these findings stem from a pilot study, and screening for thrombosis was performed only when clinically suspected, they suggest that viscoelastic testing could help identify patients at higher risk.

A hypercoagulable state may also persist into the postoperative period. Wu et al. investigated factors associated with venous thromboembolism following minimally invasive colorectal surgery. Serial measurements of D-dimer, mean platelet volume, and maximum amplitude from thromboelastography provided data for the development of a predictive risk model [24]. Although this model requires external validation before it can be incorporated into clinical practice, the findings support the dynamic assessment of coagulation during the postoperative period in oncological cases.

Studies involving patients who underwent resection for lung cancer have also reported a significant proportion of hypercoagulable viscoelastic profiles following surgery [25,26]. In these series, the predominant component of hypercoagulability appeared to vary throughout the postoperative period, with greater thrombin generation in the first few days, followed by a platelet-driven component in later phases. While these findings are of pathophysiological interest, they do not support a recommendation to replace or routinely combine antiplatelet agents with conventional anticoagulant thromboprophylaxis. This hypothesis requires prospective trials to evaluate efficacy and safety, specifically the risk of bleeding in a surgical context.

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In certain oncological procedures, such as cytoreductive surgery combined with hyperthermic intraperitoneal chemotherapy (CRS-HIPEC) and reconstructions involving microsurgical flaps, viscoelastic tests can provide relevant information during the intraoperative and postoperative periods. Mashat et al. prospectively studied 35 patients undergoing CRS-HIPEC and observed a decrease in fibrinogen levels from 3.5 to 2.1 g/L between the preoperative period and the end of the HIPEC procedure, alongside a prolongation of the INR. Intraoperative use of ROTEM® influenced clinical management, suggesting it may be useful for identifying specific abnormalities and guiding hemostatic replacement therapy.

Tuovila et al. described a dynamic evolution of the hemostatic profile, characterized by an initial phase of hypocoagulability and factor consumption, followed by a prothrombotic tendency during the hyperthermic phase [27]. Consequently, upon completion of the cytoreduction, viscoelastic testing could facilitate cautious, targeted replacement of fibrinogen and coagulation factors, thereby reducing the risk of overcorrection. Thromboelastography may also have prognostic value, as noted in a retrospective cohort of 37 patients undergoing CRS-HIPEC reported by Goder et al., the presence of a fibrinogen or coagulation factor deficit, identified via viscoelastic testing, was associated with severe postoperative complications (OR 1.53; $p = 0.05$), with no differences observed in the peritoneal carcinomatosis index or the number of resected organs [28]. Given the small sample size and the observational nature of these studies, these results should be considered exploratory.

In reconstructions involving microsurgical flaps, increased clot firmness, driven by the contribution of platelets and fibrinogen, may be associated with a higher risk of vascular pedicle thrombosis. Thakkar et al. conducted a systematic review of eight studies, encompassing 528 patients and 600 free flaps [29]. Although several studies identified associations between hypercoagulable viscoelastic parameters and flap thrombosis, there was considerable heterogeneity in study design, cutoff values, anticoagulation protocols, and the outcomes evaluated. Marsee et al. also proposed the potential utility of viscoelastic testing in microvascular reconstructions following head and neck cancer resections, procedures that require balancing the risk of hemorrhage against the risk of pedicle thrombosis [30]. Nevertheless, the current evidence remains insufficient to recommend standardized cutoff values or therapeutic interventions based solely on these tests.

A strength of the present study is that it was conducted at a specialized, high-complexity cancer center (Fundación Arturo López Pérez) and included, for the most part, high-risk procedures and patients who experienced significant intraoperative hemorrhage. More than 73% of patients experienced blood loss exceeding 1000 mL, and over 86% underwent high-risk surgery. Furthermore, no statistically significant differences were identified between the groups regarding the primary demographic and clinical characteristics recorded. These elements allow for the evaluation of ROTEM® performance in a clinical scenario where hemostatic decisions must be made rapidly.

However, the results should be interpreted with several limitations in mind. First, the retrospective, observational, "before-and-after" design precludes the establishment of causality and is subject to residual confounding, indication bias, and temporal changes in surgical, anesthetic, and transfusion practices. The gradual introduction of ROTEM® between 2020 and 2023 also implies a potential institutional learning curve. Second, the study included only patients who received at least one blood component; this introduces potential selection bias and prevents determining whether the implementation of ROTEM® reduced the overall incidence of transfusion among all patients undergoing major oncological surgery. Third, the sample size was limited ($N = 137$), which is particularly relevant when analyzing products administered infrequently or clinical outcomes that occur rarely.

The significant finding regarding fresh frozen plasma emerged from a subgroup analysis and should be interpreted with caution, given the issue of multiple comparisons and the lack of an adjusted multivariable analysis. Finally, follow-up was limited to the hospital stay; therefore, it was not possible to assess late thromboembolic events, post-discharge mortality, cancer recurrence, or other long-term outcomes.

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In summary, our results suggest that the implementation of ROTEM® may facilitate more selective hemostatic therapy and be associated with reduced exposure to fresh frozen plasma in patients undergoing complex oncological surgery. Nevertheless, due to the observational design and the already mentioned limitations, these findings should be considered hypothesis-generating. Further prospective research and multicenter studies are required; such studies should employ predefined ROTEM® algorithms, quantify the units transfused, and evaluate medium- and long-term hemorrhagic, thrombotic, and oncological outcomes.

5. Conclusions

ROTEM guided hemostatic management in major oncologic surgery allows a rapid, specific, and individualized real-time diagnosis of coagulopathy [3]. Although in our study ROTEM did not reduce overall transfusion or hospital stay, its use was associated with a significant reduction in FFP exposure in the most complex oncologic surgeries.

These findings suggest that ROTEM monitoring may be an important component in the consolidation of PBM in institutions dedicated to high-complexity oncologic surgery, although prospective studies are required to confirm its impact on clinical outcomes [16].

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. Restrictions apply to the availability of these data because they were obtained from Fundación Arturo López Pérez under institutional access and data-use restrictions and are not publicly available, subject to its data access policies and institutional permissions.

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Abbreviations

The following abbreviations are used in this manuscript:

A10	clot amplitude at 10 min
aPTT	activated partial thromboplastin time

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CCT	conventional coagulation test
CFT	clot formation time
CT	clotting time
FALP	Fundación Arturo López Pérez
FFP	fresh frozen plasma
INR	international normalized ratio
MCF	maximum clot firmness
PAI-1	plasminogen activator inhibitor-1
PBM	Patient Blood Management
PT	prothrombin time
RBC	red blood cell
ROTEM	rotational thromboelastometry
RR	relative risk
SD	standard deviation
TF	tissue factor

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