

ORIGINAL RESEARCH

Real-world data on predictors of survival in patients with gynecological tumors following pelvic arterial embolization

Camila S. S. Menezes¹ , Jesse L. da Silva¹ , Lucas Z. de Albuquerque¹ ,
Isabele A. Small¹ , Hugo R. Gouveia² , Henrique S. Martin² , Jose H. M. Luz² ,
Andreia C. de Melo^{1,*} 

¹Division of Clinical Research and Technological Development, Brazilian National Cancer Institute, 20231-050 Rio de Janeiro, RJ, Brazil

²Interventional Radiology, Brazilian National Cancer Institute, 20231-050 Rio de Janeiro, RJ, Brazil

***Correspondence**

andreia.melo@inca.gov.br
(Andreia C. de Melo)

Abstract

Background: Uterine bleeding is a potentially life-threatening complication of gynecologic malignancies. Pelvic transarterial embolization (TAE) is used for hemorrhage control, but data on outcomes and prognostic factors remain limited. This retrospective study evaluated women treated with TAE in whom cervical cancer, endometrial cancer, and radiotherapy-induced pelvic sequelae were identified within the cohort. **Methods:** Women who underwent TAE at the Brazilian National Cancer Institute (INCA) between 2019 and 2020 were included. Demographic and tumor characteristics, clinical response to TAE, and survival data were analyzed. Hemorrhage control was classified as a complete response (CR), temporary response (TempR), or no response (NR). Overall survival (OS) was estimated using the Kaplan-Meier method and compared according to response status (CR/TempR vs. NR), International Federation of Gynecology and Obstetrics (FIGO) stage (I–III vs. IV), and the presence of genitourinary fistulas. **Results:** Among 26 patients, 16 (61.5%) achieved CR, 7 (26.9%) TempR, and 3 (11.5%) NR. Patients with CR were younger, had better functional status, fewer genitourinary fistulas, and lower FIGO stages (I–III). Transfusion requirements decreased after TAE across all groups, and hemoglobin levels increased over time. Median follow-up was 23.9 months, with 19 deaths. Median OS was 5.7 months, with 12- and 24-month OS of 37.3% and 22.4%, respectively. CR was associated with improved survival ($p < 0.001$), while FIGO stage IV and fistulas were associated with worse outcomes. **Conclusions:** Pelvic TAE is a safe and minimally invasive option for hemorrhage control in gynecologic malignancies, with more favorable hemostatic outcomes largely influenced by baseline patient and disease characteristics, including younger age, lower Eastern Cooperative Oncology Group (ECOG) scores, and earlier FIGO stages.

Keywords

Embolization; Hemorrhage; Cervical cancer; Endometrial cancer; Radiotherapy sequelae

1. Introduction

In 2022, cervical cancer (CC) was reported as the fourth most frequent malignancy among women worldwide, with an estimated 660,000 new cases and approximately 350,000 deaths annually. Endometrial carcinoma (EC), although less prevalent, is responsible for an estimated 420,368 incident cases and 97,723 deaths [1]. In Brazil, the Brazilian National Cancer Institute (INCA) estimates for the 2023–2025 triennium indicate that CC remains a critical public health challenge, with 17,010 new cases expected annually, representing the third most frequent cancer in women [2, 3]. During the same period, cancer of the corpus uteri is estimated to reach 7840 new cases per year, reflecting a rising trend

linked to increasing obesity rates and an aging population [2, 4]. Despite being a preventable and treatable disease, CC continues to be disproportionately diagnosed at advanced stages in Brazil, with studies showing that more than 58% of cases are identified at stages III or IV [5, 6]. This scenario highlights the persistent disparities in prevention, early detection, and treatment, particularly in low-resource settings, where structural and socioeconomic barriers to screening are significant [4, 5].

These epidemiologic and health-system factors directly translate into a high burden of advanced disease and treatment-related complications, among which uterine bleeding—ranging from abnormal spotting to life-threatening hemorrhage—is one of the most frequent

and clinically consequential manifestations of both EC and CC. Postmenopausal bleeding is reported in the majority of patients with EC, whereas bleeding related to CC is more frequently encountered in advanced-stage disease [6, 7]. Hemorrhage can be attributed to both direct tumor erosion and radiotherapy-induced tissue injury and is a major contributor to both morbidity and mortality. Access to effective hemostatic interventions varies widely across settings, contributing to disparities in clinical outcomes [8].

In this context, the management of pelvic hemorrhage poses a major therapeutic challenge, particularly in patients with advanced disease or significant treatment-related morbidity. Over recent decades, a therapeutic transition from open surgical approaches to catheter-based, image-guided, interventional radiology techniques has been observed. Pelvic transarterial embolization (TAE) has been increasingly employed as a rapid, minimally invasive method for controlling oncologic pelvic hemorrhage, with additional benefits of symptom relief and palliation [9].

Given the growing use of TAE in this complex clinical setting and the limited data on factors influencing outcomes, this single-center retrospective study aimed to evaluate clinical factors associated with outcomes after pelvic transarterial embolization in women presenting with pelvic hemorrhage of gynecologic oncologic origin. Within the study cohort, underlying etiologies included cervical or endometrial cancer, as well as radiotherapy-induced pelvic sequelae.

2. Materials and methods

2.1 Study design, patient selection, and data collection

The Ethics in Human Research Committee of the INCA, Rio de Janeiro, approved this study protocol. All procedures were conducted in accordance with the Good Clinical Practice standards, and the reporting of this observational investigation conformed to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [10].

A retrospective review of our institutional database was conducted. All women who underwent pelvic TAE for the management of hemorrhage due to gynecologic oncologic causes between 01 February 2019 and 29 February 2020 were included. Within this cohort, the underlying etiologies included cervical cancer, endometrial cancer, and radiotherapy-induced pelvic sequelae. Exclusion criteria comprised age under 18 years, incomplete or inadequate treatment documentation, and insufficient follow-up data.

Pelvic transarterial embolization was performed in patients presenting with clinically significant hemorrhage requiring urgent intervention, as determined by a multidisciplinary team. Clinically significant hemorrhage was defined by the presence of hemodynamic instability, a substantial decrease in hemoglobin levels, and/or the need for blood transfusion despite prior conservative management.

Clinical and oncologic data were systematically collected from medical records, including sociodemographic characteristics, Eastern Cooperative Oncology Group (ECOG) Performance Status, primary tumor site and histologic subtype,

ongoing oncologic therapies, prior hemostatic procedures, previous radiotherapy exposure, and procedural details of the embolization. Tumor staging at diagnosis was assigned in accordance with the International Federation of Gynecology and Obstetrics (FIGO) 2009 classification [11, 12].

Procedures were performed at the Instituto Nacional de Câncer (INCA), Rio de Janeiro, Brazil, using a Philips Allura Xper FD20 angiography system (Best, The Netherlands). Angiographic evaluation of potential bleeding sites and/or tumoral blush was performed under spinal anesthesia or conscious sedation via common femoral artery access. The anterior divisions of both internal iliac arteries were selectively studied, and branches identified as suspicious were embolized using a 2.4–2.7 French microcatheter (Progreat®, Terumo, Tokyo, Japan). Embolization was achieved using polyvinyl alcohol particles of 400 or 500 μm (Embozene®, Varian Medical Systems, Palo Alto, CA, USA), with or without a gelatin sponge (Gelfoam®, Pfizer, New York, NY, USA) slurry, to induce vascular stasis and achieve hemostasis.

Post-procedural adverse events were classified and graded using the Cardiovascular and Interventional Radiological Society of Europe (CIRSE) Classification System for Complications. This standardized, internationally recognized scale facilitates objective, reproducible reporting based on the severity of the required treatment, ensuring robust scientific comparison with published interventional data [13].

2.2 Statistical analysis

Follow-up after TAE assessed three primary outcomes: complete response (CR), defined by the absence or minimal residual bleeding—persistent low-volume bleeding not requiring transfusion, hemodynamic support, or additional hemostatic intervention—with hemoglobin stabilization; temporary response (TempR), characterized by transient bleeding improvement that recurred during follow-up, often with a decrease in hemoglobin; and no response (NR), indicating no clinical improvement. Notably, the duration of the temporary TempR could not be consistently quantified due to heterogeneous follow-up intervals and retrospective documentation. Clinical data from medical records were correlated with these outcomes.

Clinical data were collected and managed using the Research Electronic Data Capture (REDCap) platform. Variables were summarized as medians with interquartile ranges (IQRs) for continuous data and as frequencies or percentages for categorical data. Median follow-up was estimated using the reverse Kaplan-Meier method. Overall survival (OS) was calculated from the date of TAE until death from any cause, with censoring of patients alive at last follow-up. The Kaplan-Meier method was used to estimate OS, stratified by response status (CR, TempR versus NR), FIGO stage (I–III versus IV), and presence or absence of genitourinary fistula. Hazard ratios (HR) for each variable were obtained through Cox proportional hazards analysis. Multivariate analysis was not performed due to the limited sample size. A significance threshold was set at $p < 0.05$. Missing data were excluded from analyses. Statistical analyses were conducted using R version 4.4.0 (<https://www.r-project.org/>).

3. Results

Among the 26 patients included in the analysis, 16 (61.5%) achieved a CR following TAE, while seven (26.9%) experienced a TempR, and three (11.5%) had NR. Patients with CR were generally younger, predominantly of brown or black ethnicity, non-smokers, had an Eastern Cooperative Oncology Group (ECOG) Performance Status of 1 or 2, and FIGO tumor stages of I to III. They were also less likely to present with genitourinary fistulas. Post-procedure, median blood transfusions for all cohorts decreased from 5.0 units (IQR: 4.0 to 9.0) pre-TAE to 4.0 units (IQR: 2.0 to 6.0). Hemoglobin levels showed a significant increase, rising from a median of 6.7 g/dL (IQR: 6.0 to 7.3) before TAE to 7.6 g/dL (IQR: 6.7 to 8.4) at one week, 7.8 g/dL (IQR: 6.1 to 8.2) at one month, and 8.2 g/dL (IQR: 6.7 to 10.1) at two months post-procedure (Table 1). These trends are illustrated in the box plots shown in Fig. 1, which depict the upward shift in median hemoglobin values

over time. Details on other hemostatic treatments applied, the artery selected for embolization, and the embolic agent used can be found in **Supplementary Table 1**.

The median follow-up was 23.9 months (95% confidence interval (CI): 16.2 months–not reached), during which 19 deaths occurred. The median OS was 5.7 months (95% CI: 2.6–22.3 months), with 12- and 24-month survival rates of 37.3% (95% CI: 22.4%–61.9%) and 22.4% (95% CI: 10.2%–48.8%), respectively. Patients with CR showed 12- and 24-month OS rates of 60.9% (95% CI: 40.7%–91.1%) and 36.6% (95% CI: 17.8%–74.9%), while the group with TempR or NR had a 12-month survival of zero ($p < 0.0001$) (Fig. 2). Univariable analysis identified TempR/NR as significantly associated with high mortality, with a HR of 8.43 (95% CI: 2.73–26.00; $p < 0.001$) (Table 2).

Regarding FIGO stage, 21 patients (80.8%) were classified as stages I–III, and five (19.2%) as stage IV (Table 1). Patients with stages I–III had 12- and 24-month OS rates of 46.4% (95%

TABLE 1. Patient characteristics associated with hemostatic response to pelvic transarterial embolization.

Characteristics	Complete Response n (%)	Temporary/No response n (%)	Total n (%)
Total	16 (61.5)	10 (38.5)	26 (100.0)
Median age, yr (IQR)	43.0 (34.0 to 49.2)	48.0 (43.2 to 56.5)	44.0 (34.5 to 52.8)
Ethnicity			
White	6 (37.5)	5 (50.0)	11 (42.3)
Black/brown	10 (62.5)	4 (40.0)	14 (53.8)
Missing	0 (0.0)	1 (10.0)	1 (3.8)
Smoking history			
Never	10 (62.5)	3 (30.0)	13 (50.0)
Former	2 (12.5)	1 (10.0)	3 (11.5)
Current	3 (18.8)	4 (40.0)	7 (26.9)
Missing	1 (6.2)	2 (20.0)	3 (11.5)
ECOG Performance Status			
1	3 (18.8)	0 (0.0)	3 (11.5)
2	5 (31.2)	5 (50.0)	10 (38.5)
3	4 (25.0)	5 (50.0)	9 (34.6)
4	1 (6.2)	0 (0.0)	1 (3.8)
No record	3 (18.8)	0 (0.0)	3 (11.5)
Primary tumor location			
Cervix	14 (87.5)	8 (80.0)	22 (84.6)
Uterine body	2 (12.5)	2 (20.0)	4 (15.4)
Histology			
SCC	13 (81.2)	7 (70.0)	20 (76.9)
Adenocarcinoma	2 (12.5)	2 (20.0)	4 (15.4)
Sarcoma	1 (6.2)	1 (10.0)	2 (7.7)

TABLE 1. Continued.

Characteristics	Complete Response n (%)	Temporary/No response n (%)	Total n (%)
FIGO stage			
I to III	15 (93.8)	6 (60.0)	21 (80.8)
IV	1 (6.2)	4 (40.0)	5 (19.2)
Fistula			
Present	4 (25.0)	4 (40.0)	8 (30.8)
Absent	12 (75.0)	6 (60.0)	18 (69.2)
Fistula type			
Rectovaginal	0 (0.0)	2 (20.0)	2 (7.7)
Vesicovaginal	3 (18.8)	0 (0.0)	3 (11.5)
Complex	1 (6.2)	2 (20.0)	3 (11.5)
Curative cancer treatment before TAE status			
No treatment	9 (56.2)	5 (55.6)	14 (56.0)
In progress	2 (12.5)	0 (0.0)	2 (7.7)
Complete	5 (31.2)	5 (50.0)	10 (38.5)
Curative cancer treatment before TAE description			
Surgery, radio and chemotherapy	1 (6.2)	1 (10.0)	2 (7.7)
Radio and chemotherapy	6 (37.5)	2 (20.0)	8 (30.8)
Radiotherapy	0 (0.0)	1 (10.0)	1 (3.8)
Surgery	0 (0.0)	1 (10.0)	1 (3.8)
No treatment	9 (56.2)	5 (50.0)	14 (53.8)
Clinical indication for TAE			
Tumoral bleeding	13 (81.2)	6 (60.0)	19 (73.1)
Radiotherapy sequelae	3 (18.8)	4 (40.0)	7 (26.9)
Curative cancer treatments after TAE			
None	11 (68.8)	10 (100.0)	21 (80.8)
Radio with or without chemotherapy	5 (31.2)	0 (0.0)	5 (19.2)
Palliative chemotherapy			
Before TAE	3 (18.8)	0 (0.0)	3 (11.5)
After TAE	4 (25.0)	1 (10.0)	5 (19.2)
None	9 (56.2)	8 (80.0)	17 (65.4)
Missing	0 (0.0)	1 (10.0)	1 (3.8)
Median blood transfusion prior to TAE, units (IQR)	5.0 (4.0 to 7.5)	4.5 (3.2 to 9.8)	5.0 (4.0 to 9.0)
Median blood transfusion after TAE, units (IQR)	4.0 (2.0 to 5.5)	4.5 (0.5 to 6.0)	4.0 (2.0 to 6.0)
Median hemoglobin before TAE, g/dL (IQR)	6.7 (6.0 to 7.3)	6.8 (6.2 to 7.2)	6.7 (6.0 to 7.3)
Median hemoglobin 1 week after TAE, g/dL (IQR)	7.6 (7.2 to 8.2)	7.6 (6.4 to 9.1)	7.6 (6.7 to 8.4)
Median hemoglobin 1 month after TAE, g/dL (IQR)	7.7 (6.2 to 8.6)	7.8 (5.0 to 8.2)	7.8 (6.1 to 8.2)
Median hemoglobin 2 months after TAE, g/dL (IQR)	7.9 (6.7 to 10.0)	8.4 (7.5 to 10.6)	8.2 (6.7 to 10.1)

Data are presented as n (%) and as median (IQR). IQR: interquartile range; TAE: pelvic transarterial embolization; ECOG: Eastern Cooperative Oncology Group; FIGO: The International Federation of Gynecology and Obstetrics; SCC: Squamous cell carcinoma.

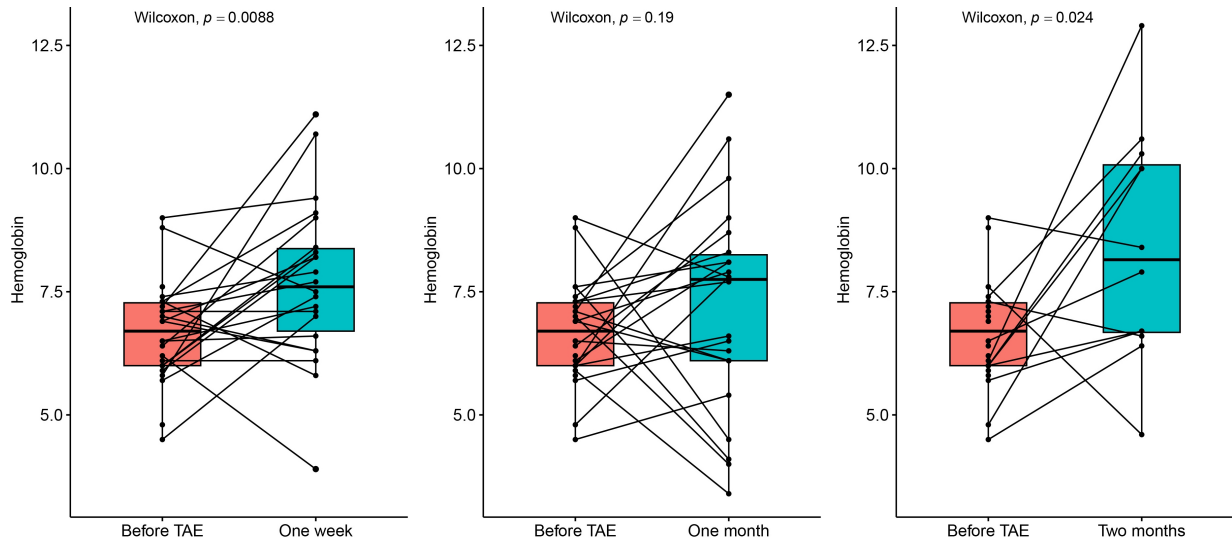


FIGURE 1. Wilcoxon test comparing hemoglobin rates before, with one week, one month, and two months after pelvic transarterial embolization (TAE). The median hemoglobin levels rose from 6.7 (IQR: 6.0 to 7.3) before the procedure to 7.6 (IQR: 6.7 to 8.4), 7.8 (IQR: 6.1 to 8.2), and 8.2 (IQR: 6.7 to 10.1) g/dL after one week, one month, and two months following the procedure, respectively.

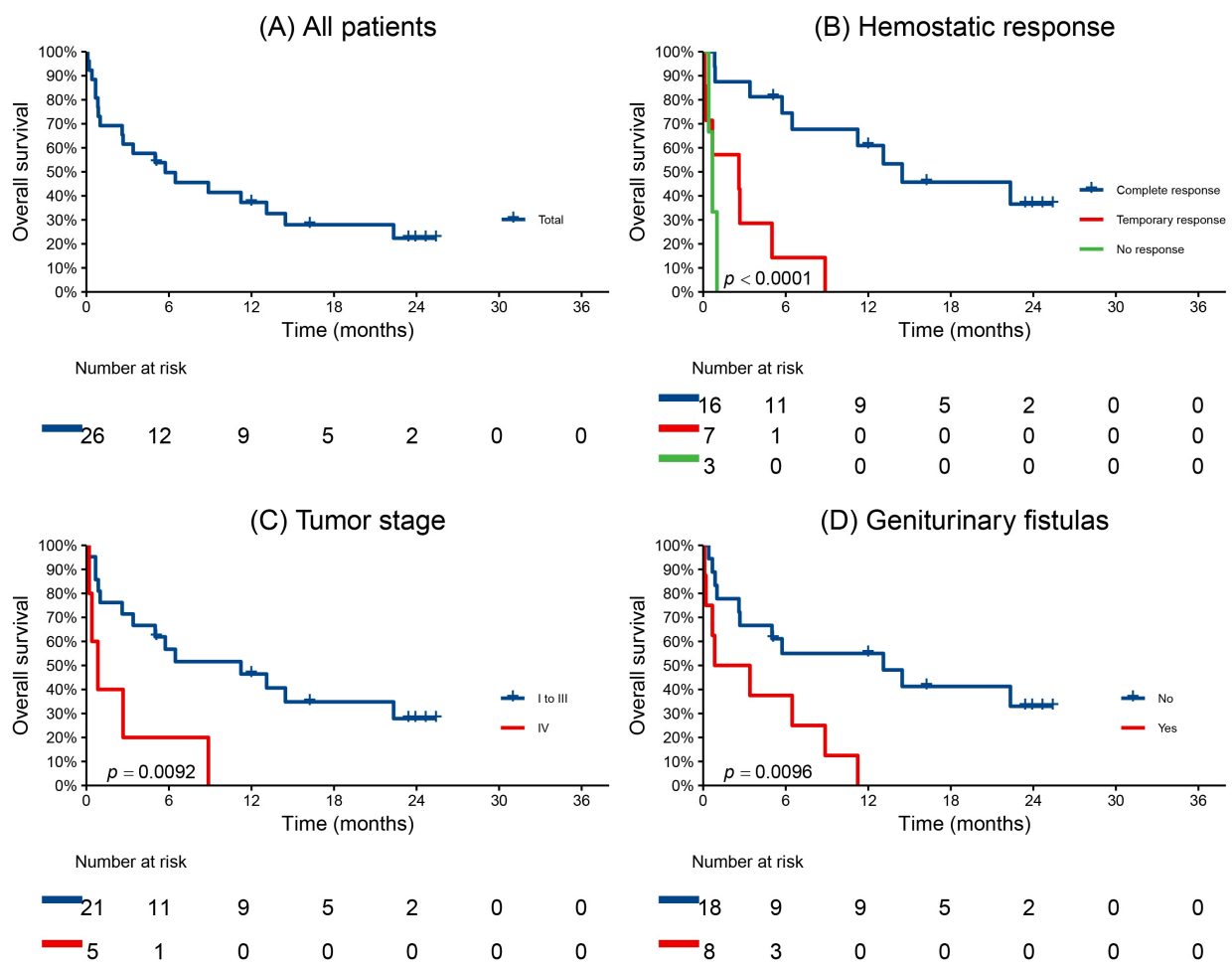


FIGURE 2. Overall survival after pelvic transarterial embolization (TAE). Kaplan-Meier OS of all patients surveyed (A), hemostatic response (B), tumoral stage (C), and genitourinary fistulas (D). The median OS after pelvic transarterial embolization (TAE) was 5.7 months (95% CI: 2.6–22.3), and 19 deaths occurred among the 26 participants during a median follow-up of 23.9 months. Patients with temporary and no response to TAE, stage IV disease, and with fistulas had a 12-month OS rate of 0% ($p < 0.05$). *Statistically significant.

TABLE 2. Univariable hazard ratios by Cox regression analysis for overall survival predictors.

Overall survival predictor	n	Univariable		
		HR	95% CI	p-value
FIGO stage IV	5	3.83	(1.29–11.42)	0.016*
TempR/NR	10	8.43	(2.73–26.00)	<0.001*
Presence of genitourinary fistulas	8	3.43	(1.27–9.23)	0.015*

HR: Hazard ratio; CI: confidence interval; FIGO: The International Federation of Gynecology and Obstetrics; TempR/NR: temporary or no response to pelvic transarterial embolization. *Statistically significant p-value.

CI: 29.1%–74.2%) and 27.9% (95% CI: 13.1%–59.3%), respectively, whereas stage IV patients had a 12-month survival of zero ($p = 0.0092$) (Fig. 2). Univariate analysis indicated stage IV disease was associated with increased mortality (HR 3.83; 95% CI: 1.29–11.42; $p = 0.016$) (Table 2). Transarterial embolization was performed with palliative intent in the majority of patients, reflecting advanced disease stage, poor performance status, or severe radiotherapy-related pelvic toxicity at presentation. A smaller subset of patients underwent TAE as a bridge-to-treatment strategy, allowing stabilization of hemorrhage and subsequent resumption or initiation of oncologic therapy.

Genitourinary fistulas were present in eight patients (30.8%), including two with a rectovaginal fistula (7.7%), three with vesicovaginal fistulas (11.5%), and three with complex fistulas (11.5%) (Table 1). Patients without fistulas had a 12-month OS rate of 55.0% (95% CI: 36.0%–83.9%) and a 24-month OS rate of 33.0% (95% CI: 15.9%–68.4%). Patients with fistulas demonstrated a 12-month OS rate of zero ($p = 0.0096$) (Fig. 2). Univariate Cox analysis showed an association between fistulas and increased mortality risk (HR 3.43; 95% CI: 1.27–9.23; $p = 0.015$) (Table 2).

Illustrative clinical case images of a patient presenting with vaginal hemorrhage secondary to CC, including a demonstrative angiogram and pre- and post-TAE magnetic resonance sequences showing effective tumor shrinkage and bleeding control, are shown in Figs. 3,4. This patient also represents one of the two cases in which TAE provided effective hemostasis, enabling the subsequent initiation of anticoagulation therapy despite simultaneous active hemorrhage and deep vein thrombosis (DVT).

Data on progression-free survival analysis are presented in **Supplementary Fig. 1** and **Supplementary Table 2**.

4. Discussion

This study addresses an important gap in the literature by evaluating prognostic factors in women undergoing pelvic transarterial embolization for gynecologic oncologic hemorrhage, in whom cervical cancer, endometrial cancer and radiation-induced tissue injury were identified within the study cohort. By extending the focus beyond immediate hemostasis, the research provides insights into long-term outcomes and factors associated with embolization prognosis in this specific patient population.

The causes of hemorrhage in this setting are heterogeneous and clinically relevant. In women with cervical and endome-

trial cancer, bleeding may result from tumor-related abnormal neovascularization or from delayed tissue injury caused by chemotherapy and/or radiotherapy [14, 15]. In the latter situation, pelvic bleeding most commonly arises from radiation cystitis or radiation proctitis, as well as from radiation-induced mucosal damage of pelvic organs [16, 17]. When present, genitourinary fistulas were considered late treatment-related sequelae rather than primary tumor-related sources of bleeding and, together with radiation-induced inflammatory changes, were often associated with fragile pelvic vessels, distorted vascular anatomy, and neovascularization, making embolization technically more challenging.

Given the severity of hemorrhage and the limitations of surgical management in advanced disease, surgical interventions for severe bleeding caused by advanced tumors are associated with substantial morbidity and mortality [18, 19]. In this context, TAE serves as a minimally invasive, effective hemostatic intervention, improving clinical outcomes [20].

Effective management of metrorrhagia and related hemorrhagic conditions, including therapies such as TAE, is essential to prevent life-threatening complications and improve clinical outcomes. This study observed a global reduction in median blood transfusions and an increase in median hemoglobin levels following TAE, creating more favorable conditions for the continuation of oncologic treatment. Nonetheless, subsequent cancer therapies were resumed in only 19.2% of patients. The relatively low proportion of patients resuming oncologic therapy likely reflects the high clinical vulnerability of this small and heterogeneous population, with many patients presenting with poor performance status, advanced disease, severe radiotherapy-related morbidity, or early death following the index hemorrhagic episode. Although the observational design limits broader applicability, these results are consistent with previous findings [21–23].

Furthermore, TAE facilitated hemostasis and enabled anticoagulation therapy in two women with concurrent hemorrhage and deep vein thrombosis, indicating its suitability for patients with simultaneous bleeding and thrombotic conditions. The procedure improved hemoglobin levels, thereby enhancing patients' ability to tolerate chemoradiotherapy. These observations supports the hypothesis that TAE may improve oncological outcomes by controlling hemorrhage, allowing radiotherapy to be fully directed at tumor eradication.

The underlying rationale for TAE involves occluding tumor-feeding vessels to achieve immediate bleeding cessation and induce tumor cytoreduction, thereby alleviating

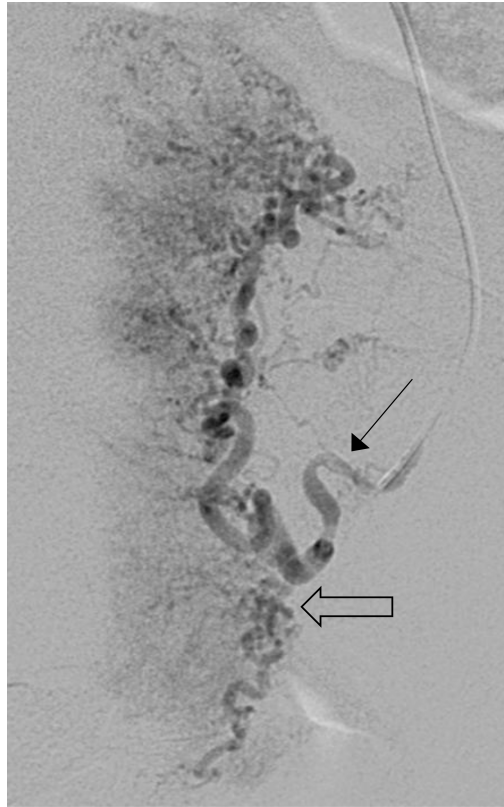


FIGURE 3. Angiogram of a cervical cancer patient presenting with vaginal hemorrhage. 37-year-old patient, presenting with vaginal hemorrhage. The patient had cervical epidermoid carcinoma, FIGO stage IIB, and was treatment-naïve. Angiogram of the left uterine artery (arrow) shows hypertrophied cervicovaginal branches (open arrow).

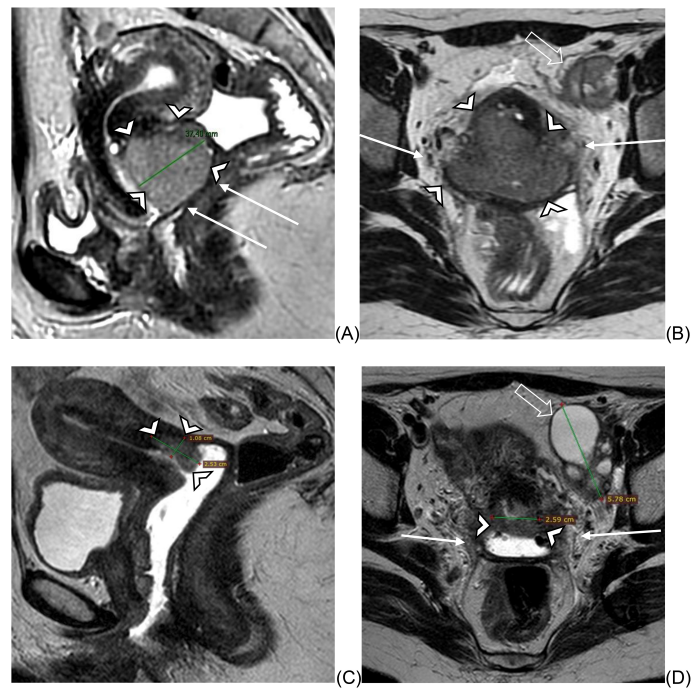


FIGURE 4. Magnetic resonance sequences of the same cervical cancer patient shown in Fig. 3, presenting with vaginal hemorrhage, before and after pelvic transarterial embolization (TAE). Magnetic Resonance T2W sequences of the same patient are represented. (A,B) images are prior embolization, showing the expansive lesion in the uterine cervix (arrowheads) measuring $4.1 \times 7.4 \times 5.1$ cm, with bilateral parametrial extension (arrows B) and upper third of the vagina (arrows in A). Lymph node enlargement in the left external iliac chain (open arrow in B). (C,D) images are after embolization, showing reduction of tumor measures to $2.5 \times 2.6 \times 1.1$ cm (arrowheads in C and D). Bilateral parametrial invasion is less visible (arrows in D). The external iliac lymph node has cystic degeneration (open arrow in D). The patient had no more vaginal hemorrhages.

symptoms caused by tumor mass effects. While rapid symptom relief can be achieved, pre-radiotherapy vessel occlusion has been hypothesized to induce intratumoral hypoxia, which may contribute to radiation resistance [13]. Additionally, factors such as anemia and poorly perfused advanced tumors further diminish intratumoral oxygenation. Nevertheless, TAE improved the patient's overall condition by increasing hemoglobin levels, enhancing tumor oxygenation and potentially optimizing the environment for effective radiotherapy [24]. Taken together, these considerations suggest a complex and potentially bidirectional interaction between pelvic transarterial embolization, tumor oxygenation, and radiotherapy response. While TAE may theoretically influence intratumoral hypoxia through vascular occlusion, it may also indirectly improve conditions for radiotherapy by correcting anemia and stabilizing the patient's clinical status. Given that this study did not assess local tumor control or radiotherapy outcomes, any inference regarding radiation sensitivity or resistance remains hypothetical and warrants further investigation in prospective studies specifically designed to address this question.

The optimal timing of TAE should account for its minimal impact on "radiocurability" outcomes; however, the procedure may pose challenges following oncologic treatments, especially after radiotherapy. Radiation-induced inflammation can compromise blood vessel integrity, resulting in fragility, thinning, and tortuosity, which complicates selective catheterization during TAE [18]. Chen *et al.* [14] reported that TAE effectively controlled metrorrhagia in 80% of patients within one-month post-radiotherapy, with no major complications. Nevertheless, previous radiotherapy, often combined with advanced-stage tumors and genitourinary fistulas, as discussed, may hinder the anti-hemorrhagic efficacy of TAE.

Univariate Cox analysis identified FIGO stage IV disease, TempR/NR, and presence of genitourinary fistulas as predictors of reduced OS in women treated with TAE for progressive CC or EC, or for radiotherapy-related pelvic complications. Conversely, the absence of genitourinary fistulas and FIGO I–III disease correlated with CR and higher survival in this population. These variables may help guide candidate selection for TAE and support individualized treatment planning, pending confirmation in multivariable and prospective studies. Hence, pelvic TAE should not be interpreted as an independent determinant of improved survival; rather, patients who achieved complete hemostatic response—characterized by younger age, better performance status, and earlier-stage disease—represent a subgroup with intrinsically more favorable prognostic features, which also predispose to a more effective response to TAE and its associated clinical benefits.

Although over 80% of patients were initially classified as FIGO stage I–III, overall survival was measured from the time of embolization rather than from diagnosis. In many cases, embolization was performed during a late, high-risk clinical phase characterized by acute hemorrhage, cumulative treatment-related toxicity, and clinical deterioration. Consequently, FIGO stage at diagnosis does not adequately reflect disease burden or prognosis at the time of embolization, and overall survival should be interpreted within this clinical context rather than as a stage-specific oncologic outcome.

Future directions in pelvic TAE are increasingly focused on the transition from subjective, operator-dependent techniques to precision-based, data-driven protocols. The integration of artificial intelligence (AI) and machine learning into intra-procedural workflows represents a major shift, as new AI-based decision support systems are being developed to provide objective, real-time quantification of perfusion to determine precise embolization endpoints [25, 26]. Furthermore, the emergence of advanced embolic technologies, such as "smart" hydrogels that respond to microenvironmental stimuli (*e.g.*, pH or temperature) and resorbable calibrated microspheres, offers the potential for more predictable vessel occlusion and reduced long-term tissue ischemia compared to traditional agents like polyvinyl alcohol particles and gel foam [27, 28]. The adoption of robotic-assisted systems and haptic feedback interfaces also promises to enhance surgical precision and minimize radiation exposure, potentially standardizing care across varying clinical settings [29]. These innovations are expected to refine hemostasis protocols by enabling a more personalized approach, tailoring embolic choice and delivery to individual tumor vascularity, ultimately improving survival and quality of life for patients with advanced gynecological malignancies.

This study presents several strengths, including a comprehensive descriptive assessment of factors associated with outcomes in patients with gynecologic cancer undergoing pelvic transarterial embolization, supported by clearly defined inclusion criteria that enhance internal validity. Nevertheless, several limitations must be acknowledged. The retrospective, single-center design is inherently subject to selection and information biases and limits the generalizability of the findings. The relatively dated research period may also limit the external validity of the findings to current clinical practice, given the evolution of diagnostic and therapeutic approaches over time. The small sample size restricts statistical power, precludes robust subgroup or multivariable analyses, and results in wide confidence intervals, particularly for survival estimates. In addition, heterogeneity in primary tumor site, disease stage, bleeding etiology (active malignancy versus radiotherapy-related sequelae), prior oncologic treatments, and clinical intent of embolization (palliative versus bridge-to-treatment) complicates data interpretation and limits causal inference regarding the impact of TAE on oncologic outcomes. Variability in follow-up duration, incomplete radiological data in some patients, and the absence of standardized assessments of local tumor control or rebleeding further constrain evaluation of long-term efficacy. Detailed radiotherapy parameters, including total dose, use of brachytherapy, and the interval between radiotherapy completion and bleeding onset, were not uniformly available and could not be systematically analyzed.

Taken together, these limitations underscore the exploratory nature of this analysis. While no definitive conclusions can be drawn, the findings provide incremental observational data and support the need for prospective, multicenter studies to better define the role of transarterial embolization in gynecologic oncologic hemorrhage.

5. Conclusions

Pelvic TAE proved to be a safe and effective, minimally invasive option for controlling severe gynecologic oncologic hemorrhage, achieving hemostasis, reducing transfusion requirements, and promoting clinical stabilization, in line with existing literature. In this cohort, clinical outcomes were mainly influenced by baseline patient and disease characteristics, such as FIGO stage and the presence of genitourinary fistulas. Patients with more favorable baseline profiles were more likely to achieve an effective hemostatic response and benefit from embolization. These findings emphasize the importance of careful patient selection and support the need for prospective studies to further define the role of transarterial embolization in the multidisciplinary management of gynecologic oncologic hemorrhage.

AVAILABILITY OF DATA AND MATERIALS

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

CSSM, ACM—conceptualization/visualization; investigation. CSSM, JLS, ACM—methodology. CSSM, LZA, IAS, ACM, JHML, HSM, HRG—data curation/formal analysis/software. CSSM, JLS, LZA—data verification. ACM—project administration/supervision. CSSM, JLS, LZA, ACM—writing the original draft. All authors reviewed and edited. All authors read and approved the final manuscript and had final responsibility for the decision to submit it for publication.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethics approval was obtained from the Institutional Review Board (Comitê de Ética em Pesquisa do Instituto Nacional de Câncer, CEP-INCA, CAAE 24350819.0.0000.5274) and the study was conducted in accordance with Good Clinical Practice guidelines. Due to its observational retrospective design, the board waived the requirement for informed consent from all patients.

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CONFLICT OF INTEREST

Andreia Cristina De Melo is serving as one of the Editorial Board members of this journal. We declare that Andreia Cristina De Melo had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to EH.

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SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at <https://oss.ejgo.net/files/article/2110255567194734592/attachment/Supplementary%20material.docx>.

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