Interventional Radiologists Achieve Equivalent Outcomes and Lower Costs for Totally Implantable Venous Access Device Placement Compared to Operating Room Placement

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ABSTRACT

Purpose: To compare the cost and outcomes of surgical and interventional radiology (IR) placement of totally implantable venous access devices (TIVADs) within a large regional health system to determine the service line with better outcomes and lower costs to the health system.

Materials and Methods: A retrospective review of all chest port placements performed in the operating room (OR) and IR suite over 12 months was conducted at a large, integrated health system with 6 major hospitals. Secondary electronic health record and cost data were used to identify TIVAD placements, follow-up procedures indicating port malfunction, early adverse events (within 1 month after the surgery), late adverse events (2–12 months after the procedure), and health system cost of TIVAD placement and management.

Results: For 799 total port placements included in this analysis, the rate of major adverse events was 1.3% and 1.9% for the IR and OR groups, respectively, during the early follow-up (P = .5655) and 4.9% and 2.8% for the IR and OR groups, respectively, during the late follow-up (P = .5437). Malfunction-related follow-up procedure rates were 1.8% and 2.6% for the IR and OR groups, respectively, during the early follow-up (P = .4787) and 12.4% and 10.5% for the IR and OR groups, respectively, during the late follow-up (P = .4354). The mean cost of port placement per patient was $4,509 and $5,247 for the IR and OR groups, respectively. The difference in per-patient cost of port placement was $1,170 greater for the OR group (P = .0074).

Conclusions: The similar rates of adverse events and follow-up procedures and significant differences in insertion cost suggest that IR TIVAD placement may be more cost effective than surgical placement without affecting the quality.

ABBREVIATIONS

BI = business intelligence, CI = confidence interval, CPT = Current Procedural Terminology, ICD-10 = *International Classification of Diseases, Tenth Revision*, IR = interventional radiology, OR = operating room, TIVAD = totally implantable venous access device, TPA = tissue plasminogen activator

Since the first surgical implantation in 1982, utilization of totally implantable venous access devices (TIVADs) has been steadily increasing, concurrent with advances in chemotherapy, safety and durability of apparatuses, and cosmetic improvements (1–4). Originally being a surgical procedure, TIVAD implantation was started in 1992 by interventional radiologists using image guidance (5). The transition to interventional radiology (IR) placement was prompted partially by literature (2,3,6–8) supporting that IR procedures were less expensive, required less operative time, resulted in reduced morbidity, and had higher placement success with more accurate positioning. Further investigations (1,9–11) comparing the costs between surgical placement in the operating room (OR) and IR have reported inconsistent findings. The conflicting results published in previous studies highlight the need to clarify potential differences in OR and IR port placement costs and outcomes.

The purpose of this study was to compare outcomes and costs of surgical and IR TIVAD placement across a large

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RESEARCH HIGHLIGHTS

- In this study of 799 placements of totally implanted vascular access devices (TIVAD), similar outcomes were achieved when comparing surgical placement in the operating room to placement by interventional radiology (IR).
- Cost of TIVAD insertion is significantly higher per patient for surgical placement in the operating room compared to IR.
- Similar rates of adverse events and follow-up procedures with reduced costs realized in IR TIVAD placements demonstrated greater cost efficiency in IR without compromising quality.

STUDY DETAILS

Study Type: Retrospective, observational, cohort study

Level of Evidence: 3 (SIR-C)

health system to determine which service line has better outcomes and lower costs. This study will help clinicians and hospital administrators make value-driven clinical decisions while maintaining or improving the quality of care for patients receiving TIVADs for long-term treatment.

MATERIALS AND METHODS

This retrospective observational study analyzed consecutively placed TIVADs by surgeons and interventional radiologists between January 1, 2017, and December 31, 2017, across a single regional health system with 6 major hospitals. All patients in the IR group were treated at the flagship, 814-bed tertiary hospital in the IR suite, and those in the OR group were treated in the ORs of all 6 major hospitals, 84% of which came from the flagship hospitals. An institutional review board (Committee-A of the Greenville Health System, Greenville, South Carolina) approved this study and waived informed consent.

Data Extraction

Patient data were acquired through the hospital system business intelligence (BI) department that maintains a database of patient, encounter, and charge data and assigns cost at the charge level for internal reporting. Patient demographic characteristics, encounter data (discharge date and facility), coding data (diagnostic and procedural codes), billing data (charges and revenue center), and cost were extracted from the BI database for all patients (aged 18 or older) who received TIVAD implantation between January 1, 2017, and December 31, 2017. In addition, data for all encounters up to 12 months after initial TIVAD placement were extracted to provide a standardized follow-up period for a cost and outcome analysis. The BI department routinely performs data validation. Additionally, the study team manually audited the data extracted for this analysis to ensure accurate representation of port placement and outcomes of interest.

TIVAD Placement

Patients receiving TIVADs were identified using a list of Current Procedural Terminology (CPT) codes used to bill for port implantation procedures by the departments of surgery and radiology (Table 1). All subsequent port placements coded after the initial implantation were considered replacements. Patients were classified by service line (OR vs IR) using the "Revenue Center" charge attribution field. The accounting department uses revenue centers to categorize charges by type across all facilities. The classification of IR and OR study groups was based on the presence or absence of OR charges:

1. If any charges were billed to the "Operating Room" Revenue Center for a port implantation encounter, the patient was assigned to the OR group.
2. If there were charges billed to the "Radiology" or "Special Radiological Procedures" revenue centers and there were no "Operating Room" charges for a port implantation encounter, the patient was assigned to the IR group.

Using revenue centers ensured accurate classification of operators because only interventional radiologists perform port implantation in the IR suite and only surgical operators perform port implantation in the OR at the study site. A detailed overview of inclusion criteria and patient classification is shown in the Figure.

Anesthetic services were used under rare circumstances when moderate sedation was deemed unsafe or not tolerated in the observed IR department, whereas port insertion in the OR was always performed under anesthesia. All patients received prophylactic antibiotic therapy, usually cefazolin. IR placements were performed under ultrasound-guided internal jugular vein access, preferably the right internal jugular vein. OR placements were performed using bilateral internal jugular vein and bilateral subclavian vein access with or without ultrasound guidance. The study institution exclusively used the Power Port (Bard, Murray Hill, New Jersey) in the IR and OR groups. Skin closure was performed with absorbable polyglactyl sutures (Vicryl;

Table 1. TIVAD Placement and Follow-up Procedure CPT Codes

Procedures	ICD-10-CM codes
Port placement	36557, 36558, 36560, 36561, 36563, 36565, 36566
Port replacement, repositioning, or repair	36575, 36576, 36578, 36580, 36581, 36582, 36583, 36585, 36597
Port checks	36598
Tissue plasminogen activator administration	36593
Fibrin sheath removal	36595, 75901, 36596, 75902

CPT = Current Procedural Terminology; TIVAD = totally implantable venous access device.

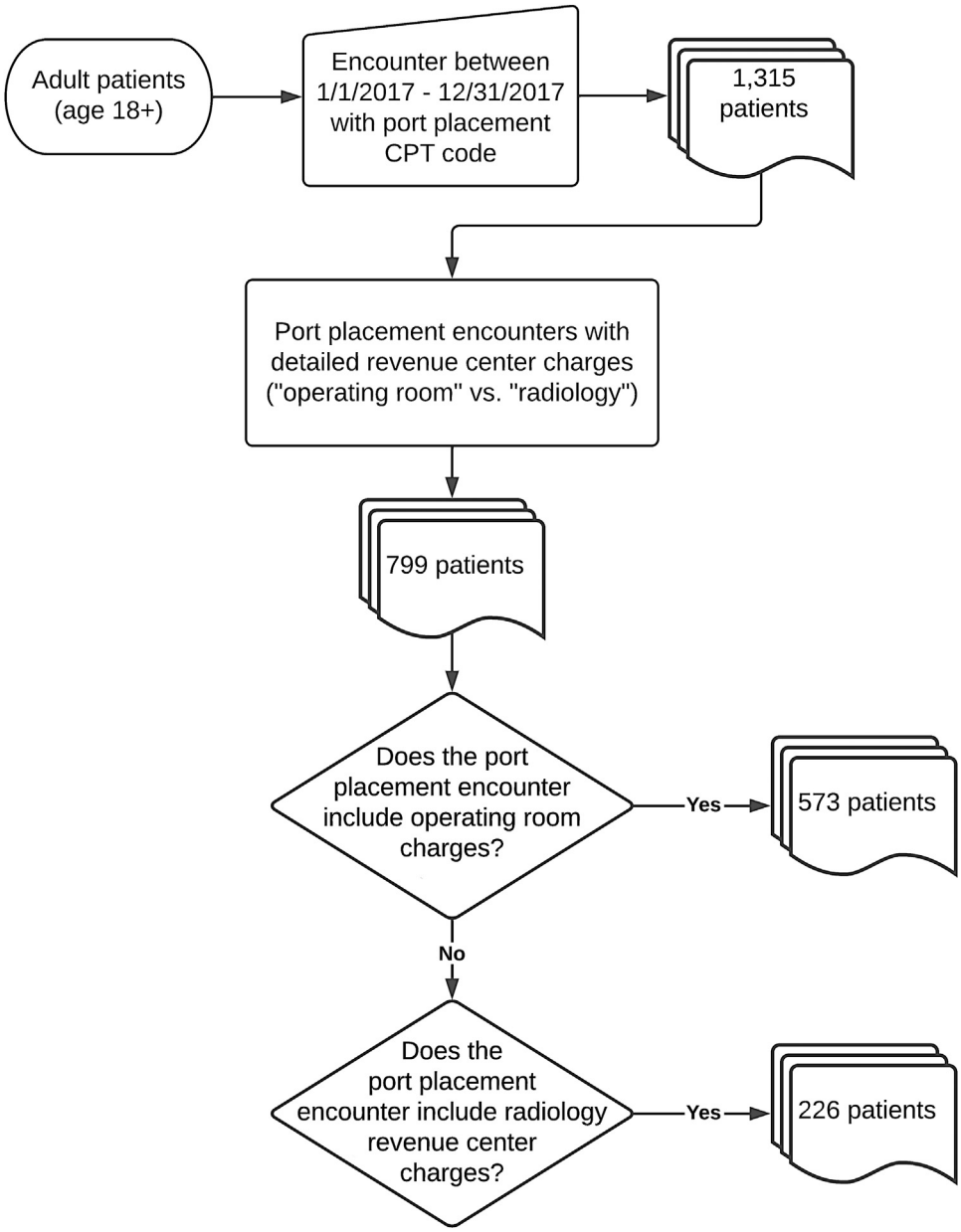

Figure. Totally implanted vascular access devices: patient selection and placement classification. Inclusion criteria were all patients aged ≥18 years with an encounter containing a Current Procedural Terminology (CPT) code for port insertion (Table 1) that occurred between January 1, 2017, and December 31, 2017. The study group classification was based on revenue center charges.

Ethicon, New Brunswick, New Jersey) sutures and 2-octyl cyanoacrylate skin adhesive (Dermabond; Ethicon). In the IR protocol, ports were left accessible if the port were to be used the same day for an infusion or computed tomography scan. Otherwise, the port was locked with heparinized saline and the Huber needle was removed.

Clinical Outcomes

Adverse events and follow-up procedures were identified using the *International Classification of Diseases, Tenth Revision, Clinical Modification* (ICD-10-CM) diagnostic codes and CPT codes for subsequent encounters during the 12 months after initial TIVAD implantation for each patient. All observed outcomes were divided into 2 categories by the time of diagnosis: early (within 30 days of port implantation) and late (between 30 and 365 days after port implantation). The follow-up procedures assessed in this analysis as indications of port malfunction or occlusion included port replacement, repositioning, repair, port checks with imaging, fibrin sheath removal, or administration of tissue plasminogen activator (TPA). These follow-up procedures were identified using CPT codes provided by the radiology department at the study site (Table 1). Adverse events in this analysis were identified and classified as major or minor based on the Society of Interventional

Table 2. TIVAD Adverse Event ICD-10-CM Codes

Adverse event type	ICD-10-CM codes
Pneumothorax	J9381, J9383, J939, J95811
Hemothorax	J942
Hematoma	I9762, I97621, I97630, I97631, I97638
Embolism	T82818A, T82818D, T82818S
Dehiscence	T8131XA, T8131XD, T8131XS
Infection	T80212A, T80212D, T80212S, T80218A, T80218D, T80218S, T80219A, T80219D, T80219S, T80211A, T80211D, T80211S
Thrombosis	T82868A, T82868D, T82868S
Catheter displacement	T82817A, T82818A, T82817D, T82818D
Inflammation	T827XXA, T827XXD, T827XXS
Pain	T82848A, T82848D, T82848S
Port leakage	T82538A, T82538D, T82538S, T8243XA, T8243XD, T8243XS, T82534A, T82534D, T82534S
Mechanical complication	T82518A, T82518D, T82518S, T82519A, T82519D, T82519S, T82598A, T82598D, T82598S, T82599A, T82599D, T82599S, T8241XA, T8241XD, T8241XS, T82514A, T82514D, T82514S, T82594A, T82594D, T82594S

ICD-10-CM = *International Classification of Diseases, Tenth Revision, Clinical Modification*; TIVAD = totally implanted vascular access device.

Radiology Quality Improvement Guidelines for Central Venous Access.(12). The major adverse events included pneumothorax, hemothorax, hematoma, embolism, dehiscence, infection, and thrombosis. The minor adverse events included catheter displacement, port leakage, other mechanical adverse events, inflammation, and pain. ICD-10 codes used to identify adverse events are listed in Table 2. The clinical outcomes assessed in this analysis were attributed to each initial port placement classification. Clinical indications for port placement were determined by the ICD-10 codes listed as the primary diagnosis for each patient's initial TIVAD placement encounter and categorized using the Clinical Classification System Refined tool developed by the Agency for Healthcare Research and Quality (13).

Cost Analysis

The cost calculations were acquired from the BI department and incorporated professional service fees, procedures, supplies, medications, anesthesia, payroll, and equipment. The cost accounting process performed at the study site involved a hybrid methodology using the ratio of cost to charge and activity-based costing to assign costs to all charges billed for by the hospital on a monthly basis. The cost assigned to each charge billed for a patient encounter was aggregated to determine the total cost of an encounter.

Statistical Analysis

The Welch *t* test and chi-square analysis were used to evaluate the differences in demographic variables and indications for port insertion between the 2 study groups. Univariate and multivariate regression models were used to determine whether the following variables were associated with the development of overall, early, or late adverse events: patient age, sex, race, clinical indication for port placement, and port placement group (IR or OR). Multivariate logistic regression adjusting for patient age, sex, race, and indication for port placement was used to estimate the association between the port placement group and rate of adverse events and follow-up procedures and the association between the port placement group and cost of port placement and cost of managing port-related outcomes. All analyses were conducted using the SAS analytical software (SAS, Cary, North Carolina), and statistical significance was determined at a level of $P < 0.05$.

RESULTS

The final analysis included 799 patients; port implantation was performed for 226 patients in the IR suite and for 573 patients in the OR. There were no statistically significant differences in patient demographic variables between the 2 study groups based on the *t* test analysis for age ($P = .5226$) and the chi-square analysis for sex ($P = .0669$) and race ($P = .5665$). However, the clinical indications for TIVAD placement varied significantly between the study groups ($P < .0001$). Because of the significant variance in clinical indications for port placement and slight differences in demographic characteristics between the 2 study groups, multivariate regression adjusting for these baseline variables provides a more accurate estimation of the relationship between the port placement group and cost and outcomes. Comparisons of patient demographic characteristics and indications for TIVAD placement between the IR and OR groups are summarized in Table 3.

Follow-up Procedures

Port malfunction–related follow-up procedures, which included port replacement, repair, repositioning, and removal; port checks using contrast injections and x-ray imaging; TPA administration for thrombolysis; and endovascular fibrin sheath removal, were similar among the IR and OR groups for both early ($P = .4787$) and late ($P = .4354$) periods. Follow-up procedures were performed for 4 (1.8%) patients and 15 (2.6%) patients during the early follow-up and 28 (12.4%) patients and 60 (10.5%) patients during the late follow-up in the IR and OR groups, respectively. Adjustments for patient age, sex, race, and indication for port placement with logistic regression modeling confirmed no statistically significant differences in odds of requiring follow-up procedures between IR and OR placement ($P = .5703$). A comparison of malfunction-related follow-up procedures between the study groups is tabulated in Table 4.

Adverse Events

Port-related adverse events indicated by ICD-10 codes were similar between the study groups. Early major adverse

Table 3. Patient Demographic Characteristics and Clinical Indications for TIVAD Placement in OR versus IR Groups

Demographic characteristic		IR group, n (%)	OR group, n (%)	*P* value
All	Patients	226 (28.3)	573 (71.7)	
Sex	Female	116 (51.3)	335 (58.5)	.0669
	Male	110 (48.7)	238 (41.5)	
Age, y	Mean age (SD)	60.5 (14.0)	59.8 (14.0)	.5226
	Range	20–90	18–90	
Race	White or Caucasian	166 (73.5)	438 (76.4)	.5665
	Black or African American	52 (23.0)	110 (19.2)	
	Hispanic	6 (2.7)	17 (3.0)	
	Asian	0 (0.0)	5 (0.9)	
	Biracial or multiracial	1 (0.4)	1 (0.2)	
	Other, patient refused, unknown	1 (0.4)	2 (0.4)	
Cancer indications for port placement	Solid tumor cancers	116 (51.3)	486 (84.8)	<.0001
	Hematological cancers	47 (20.8)	42 (7.3)	
Noncancer indications for port placement	All noncancer indications	63 (27.9)	45 (7.9)	<.0001
	Chronic kidney disease	18 (8.0)	4 (0.7)	
	Complication of cardiovascular device, implant, or graft	6 (2.7)	16 (2.8)	
	Implant-, device-, or graft-related encounters	6 (2.7)	5 (0.9)	
	Amyotrophic lateral sclerosis	11 (4.9)	0 (0.0)	
	Other noncancer indications	22 (9.7)	20 (3.5)	

IR = interventional radiology; OR = operating room; SD = standard deviation; TIVAD = totally implanted vascular access device.

Table 4. TIVAD Follow-up Procedures

TIVAD follow-up procedures	Early follow-up procedures (≤30 d after placement)			Late follow-up procedures (>30 d after placement)		
	IR group, n (%)	OR group, n (%)	*P* value	IR group, n (%)	OR group, n (%)	*P* value
Any follow-up procedure	4 (1.8)	15 (2.6)	.4787	28 (12.4)	60 (10.5)	.4354
Replacement, reposition, or repair	3 (1.3)	8 (1.4)	.9402	14 (6.2)	19 (3.3)	.0702
Port check	1 (0.3)	5 (0.9)	.5339	5 (2.2)	11 (1.9)	.7905
Tissue plasminogen activator administration	0 (0.0)	2 (0.4)	.9781	12 (5.3)	44 (7.7)	.2404
Fibrin sheath removal	0 (0.0)	0 (0.0)		1 (0.4)	3 (0.5)	.8839

IR = interventional radiology; OR = operating room; TIVAD = totally implantable venous access device.

events occurred in 3 (1.3%) and 11 (1.9%) patients in the IR and OR groups, respectively ($P = .5655$). Late major adverse events occurred in 11 (4.9%) and 16 (2.8%) patients in the IR and OR groups, respectively ($P = .5437$). The difference in adverse event rates between the IR and OR groups, after adjusting for patient age, sex, race, and indication for port placement, was not statistically significant for the total ($P = .1703$), early ($P = .1026$), or late ($P = .7867$) follow-up periods. A comparison of TIVAD adverse events between the study groups is summarized in Table 5.

Indications for Port Placement

The multivariate analysis of indication for port placement, patient demographic characteristics (age, race, and sex), and port placement group (IR and OR) determined indication for port placement to be the only variable with a statistically significant association with the likelihood of adverse events during the 12-month follow-up ($P < .0001$). In particular, mesothelioma, leukemia, and urinary system cancers were associated with the greatest odds of adverse events after port placement. In addition, variance in clinical indications for port placement was significantly associated with port placement costs ($P < .0001$) and cost of port follow-up procedures and managing adverse events ($P = .0012$).

Cost

The mean total costs of port placement per patient were $5,038 for all patients, $4,509 (95% confidence interval [CI], $3,744–$5,273) for the IR group and $5,247 (95% CI, $4,944–$5,550) for the OR group. The interquartile range of placement costs were $2,219–$5,213 and $3,541–$5,498 for the IR and OR groups, respectively. The mean total costs of follow-up procedures and managing port-related adverse events per patient were $1,758 (95% CI, $891–$2,625) and $2,012 (95% CI, $1,374–$2,649) for the IR and OR groups, respectively. Using multiple linear regression modeling to adjust for patient age, sex, and race and indication for port placement, the per-patient cost of OR port placement was

Table 5. TIVAD Adverse Events

TIVAD adverse event	Early adverse events (≤30 d after port placement)			Late adverse events (>30 d after port placement)		
	IR group, n (%)	OR group, n (%)	*P* value	IR group, n (%)	OR group, n (%)	*P* value
Major adverse event	3 (1.3)	11 (1.9)	.5655	11 (4.9)	16 (2.8)	.5437
Pneumothorax	0 (0.0)	1 (0.2)	.9794	0 (0.0)	0 (0.0)	
Hemothorax	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Hematoma	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Embolism	0 (0.0)	0 (0.0)		0 (0.0)	1 (0.2)	.9794
Dehiscence	0 (0.0)	3 (0.5)	.9774	3 (1.3)	5 (0.9)	.5638
Infection	3 (1.3)	3 (0.5)	.2530	5 (2.2)	6 (1.1)	.2138
Thrombosis	0 (0.0)	5 (0.9)	.9764	5 (2.2)	4 (0.7)	.0839
Minor adverse event	9 (4.0)	15 (2.6)	.3088	10 (4.4)	23 (4.0)	.7927
Catheter displacement	1 (0.4)	2 (0.4)	.8462	1 (0.4)	6 (1.1)	.4234
Inflammation	2 (0.8)	4 (0.7)	.7834	5 (2.2)	5 (0.9)	.1390
Pain	2 (0.9)	1 (0.2)	.1843	0 (0.0)	3 (0.5)	.9774
Port leakage	0 (0.0)	1 (0.2)	.9794	1 (0.4)	0 (0.0)	.9767
Mechanical complication	5 (2.2)	9 (1.6)	.5357	6 (2.7)	13 (2.3)	.7473

IR = interventional radiology; OR = operating room; TIVAD = totally implantable venous access device.

determined as $1,596 greater than that of IR placement ($P < .0001$). Using the same adjusted model, the difference in the cost of follow-up procedures and managing adverse events between the OR and IR groups was not statistically significant ($P = .1051$).

DISCUSSION

Value-based health care encourages greater cost efficiency while maintaining the quality of care and outcomes. Conflicting evidence from previous research comparing cost and outcomes for port placement in IR and OR settings highlights the need for further investigation into the cost and outcomes of these 2 care pathways. Previous comparative analyses of radiological and surgical placements (1,7,9,11) found fewer adverse events and placement failures with IR, greater early adverse events among IR placement, and similar adverse event rates between IR and OR placements. Studies comparing the costs of OR and IR placement have also produced inconsistent findings. LaRoy et al (9) and Feo et al (10) determined costs to be roughly 2 times greater for OR placement than that for IR placement. However, OR placement costs were found to be 15% lower by Marcy et al (13) and $749 lower per patient by Sticca et al (1). The inconsistency in reported rates of adverse events and cost of port placement was likely because of inherent heterogeneity between different hospital departments and service lines and variance in the cost calculation.

This study suggests that the differences in health system costs of chest port placement and treatment of subsequent adverse events are significantly lower when performed in the IR suite compared to the OR. Furthermore, port adverse events and follow-up procedures were similar between the IR- and OR-placed ports. Lower costs and similar outcomes observed in the IR group of this study provide a potential rationale for TIVAD implantations to be performed by interventional radiologists at integrated health systems with managed care operations.

Although facilitating a larger analysis, this study was limited in clinical accuracy and granularity by using CPT and ICD-10 codes to identify port placements, follow-up procedures, and adverse events. Billing data from the electronic health record system did not provide the same clinical detail and accuracy level as the manual chart review used in a previous study (14). Rates of adverse events and follow-up procedures were normalized by patients rather than by catheter days in this analysis because of the potential for inconsistent coding of port removal or replacement. However, not accounting for varying lengths of dwell time is a significant limitation in the validity of this comparison between rates of port-related events. Furthermore, some of the follow-up procedures may not always indicate a problem with the port. For example, port checks and TPA administration could indicate port mismanagement rather than a problem from port placement. Finally, this study assumed that coding processes and accuracy were similar between surgical and radiological departments from the same organization to allow a valid comparison.

Furthermore, the comparison between 2 distinct departments within a hospital or health system is also limited in internal validity by differences in structure and operations. The organizational setting for this study included 1 IR suite and 6 major hospital ORs, although most of the OR port insertions were performed at the primary hospital OR (84% of patients in the OR). Port insertion in the IR suite was performed by the same 4 attending physicians and 2 physician assistants. OR port insertion was performed by a different group of surgeons at 2 of the hospitals included in this study. Surgical placement involves significantly more heterogeneity with many attendings, physician assistants, residents, and fellows across many subspecialties. Other limitations in comparing IR with OR placement include adverse event tracking mechanisms used by surgeons (the

National Surgical Quality Improvement Program), which are not used by interventional radiologists; differing levels of surgeon/radiologist experience and placement techniques used; differing vascular access site selection; and potential for selection bias due to incongruent referral patterns. Another source of heterogeneity between the study groups was follow-up care. Patients who died or were lost to follow-up were not identified in this analysis. In this study's health system, surgically placed ports that fail are sometimes referred to IR but not vice versa. It is challenging to standardize port management at a large integrated health system with several infusion centers covering a significant geographic area. General anesthesia, a significant driver of cost, was included in all cost calculations; however, it is rarely used in the IR setting, whereas the OR setting always uses anesthesia for port implantation. This analysis did not account for these differences in departmental structures and operations, but the results remain generalizable because this is the reality for many integrated health systems.

In conclusion, this study found equivalent rates of adverse events and follow-up procedures from TIVAD insertion among surgical and interventional radiological placements and significantly greater cost of insertion and management of adverse events for surgical placements. These findings suggest that TIVAD placements in the IR setting are more cost effective with no difference in the quality of care. Although a comparison between 2 distinct departments at a large integrated health system is limited by inherent heterogeneity, this is the reality at many health care systems. The generalizability of these results depends on many factors addressed in the limitations of this study, but the scalable methodology of this analysis based on standardized diagnosis and procedure coding will allow for the application of these results to a variety of health care settings. Clinically integrated networks, health information exchanges, and large public datasets provide opportunities for even a larger analysis using a similar methodology that will clarify the validity of these results and the true nature of cost efficiency and quality of care for surgical and radiological port insertions.

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