The Role of Physician-Driven Device Preference in the Cost Variation of Common Interventional Radiology Procedures

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ABSTRACT

Purpose: To analyze the impact of physician-specific equipment preference on cost variation for procedures typically performed by interventional radiologists at a tertiary care academic hospital.

Materials and Methods: From October 2017 to October 2019, data on all expendable items used by 9 interventional radiologists for 11 common interventional radiology procedure categories were compiled from the hospital analytics system. This search yielded a final dataset of 44,654 items used in 2,121 procedures of 11 different categories. The mean cost per case for each physician as well as the mean, standard deviation, and coefficient of variation (CV) of the mean cost per case across physicians were calculated. The proportion of spending by item type was compared across physicians for 2 high-variation, high-volume procedures. The relationship between the mean cost per case and case volume was examined using linear regression.

Results: There was a high variability within each procedure, with the highest and the lowest CV for radioembolization administration (56.6%) and transjugular liver biopsy (4.9%), respectively. Variation in transarterial chemoembolization cost was mainly driven by microcatheters/microwires, while for nephrostomy, the main drivers were catheters/wires and access sets. Mean spending by physician was not significantly correlated with case volume (P =.584).

Conclusions: Physicians vary in their item selection even for standard procedures. While the financial impact of these differences vary across procedures, these findings suggest that standardization may offer an opportunity for cost savings.

ABBREVIATIONS

CV = coefficient of variation, SD = standard deviation, TARE = transarterial radioembolization, UFE = uterine artery embolization for fibroids

As spending on health care approaches one fifth of the gross domestic product of the United States, the focus on value and cost-efficiency continues to be a priority in health care delivery. As a specialty, interventional radiology (IR) is aligned with these goals, replacing some high-cost, more invasive surgical options with procedures that are less invasive and often less costly (1). As treatment options offered by IR continue to grow, an emerging body of literature has focused on comparing costs associated with expendable supplies (2-4). Physician decision-making is now being emphasized as a potential mechanism for controlling costs by encouraging cost-conscious choices on frequently used devices (5). However, studies show that physicians, including interventional radiologists, are often uninformed about the cost of frequently used devices (6-12).

This study investigates cost variation due to physician-specific item selection for frequently performed IR procedures at an academic tertiary center.

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RESEARCH HIGHLIGHTS

- Physician-driven selection and utilization of devices may result in substantial impact on non-labor costs borne by an institution.
- Wide inter-physician variability of devices used and costs incurred within a single practice was demonstrated for commonly performed interventional radiology procedures.
- Standardization of high-cost, high-variation devices could allow for cost savings, and thus improved value of interventional radiology care.

MATERIALS AND METHODS

Data Source

This single-center, retrospective study was exempt from an institutional review board approval since it did not meet the definition of human subjects' research based on the absence of patient identifiers as defined by the Health Insurance Portability and Accountability Act.

Data for all expendable items (implantable and disposable supplies, including devices) used for a set of representative de novo percutaneous and endovascular procedures performed by IR between October 2017 and October 2019 were extracted from the electronic medical record using an enterprise-wide, institutional clinical analytics tool called Supply Chain Variation Discovery App. This interface is a proprietary tool that identifies high surgical supply utilization and costs to help drive down inappropriate variation to reduce supply expenses. The timeframe was restricted to 2 years to allow an adequate sample size, but limit fluctuations in cost. The procedures included abscess drainage, internal-external biliary drainage, cholecystostomy, nephrostomy, nephroureteral stent placement, tunneled pleural and peritoneal drainage, enteral feeding tubes, transjugular liver biopsy, inferior vena cava filter placement, uterine artery embolization for fibroids (UFE), portal vein embolization, transarterial chemoembolization, and transarterial radioembolization (TARE). Complex and variable procedures, such as transjugular intrahepatic portosystemic shunts, acute and chronic venous recanalization, and nontumor embolization, were excluded to allow a comparison of costs.

The following data variables were extracted: type of procedure (procedure category), operator, total and individual physician volume within each procedure category, expendable item (including all disposable/implantable devices) name and code, unit cost for all items (cost to the hospital), number of units used, and the total cost for items for each procedure. The extracted data were limited to full-time, board-certified IR faculty; per diem and advanced practice providers were excluded as they were not present during the full 2-year time frame. Procedure categories with <30 total procedures were excluded as well as physicians who had completed only 1 case of a procedure in the said time frame. Spending outliers were manually examined for quality control. Post hoc quality check revealed missing data for de novo nephroureteral stents and inferior vena cava filter placement, and therefore, both procedures were excluded from analyses. Thus, the final data set included abscess drain placement, internal-external biliary drain placement, cholecystostomy, nephrostomy, gastrostomy and gastrojejunostomy, transjugular liver biopsy, UFE, transarterial chemoembolization, and TARE (preparatory angiography and administration).

Measured Outcomes and Statistical Analyses

The primary outcomes of interest were measures of variation across physicians in the cost of items per case by procedure category. The mean supply cost per procedure was calculated by dividing the total cost by the total number of cases, grouped by physicians. The mean, minimum, maximum, and standard deviation (SD) of the costs per case across physicians were then calculated for each procedure category. The coefficient of variation (CV) or relative SD was calculated as the percentage ratio of SD to the mean to provide a relative comparison of variation in spending, while controlling for differences in the mean cost across procedure categories.

Procedure categories performed by at least two thirds of the interventional radiologists with a CV higher than the 50th percentile and volumes >100 procedures were then selected to identify the item-specific drivers of cost. Within each resultant procedure category, the cost per item type was compared across physicians. All items were collated into broad types, which included access (needles, sheaths), contrast agents, drainage catheter (nonlocking and locking-loop drainage catheters), base catheters and wires (typically 5-F catheters and 0.035 wires), microcatheters and microwires (2.1–2.8-F catheters and 0.014–0.016 microwires), balloon dilatation catheters, coils/micro-coils, administered embolics (including microspheres), and radioembolic microspheres. Syringes, saline, trays, and drapes were grouped into the other category.

The final analysis aimed to examine whether physician experience impacts cost. Case volume per physician was used as a surrogate for physician experience. First, ordinary least squares regressions of the mean cost versus case volume for each procedure category were separately performed to examine whether the relationship was dependent on the procedure type. Then, with the entire dataset, an ordinary least squares regression of the mean cost by case volume was performed with the procedure category as a second independent variable to control for differences in the mean cost of a procedure and clustering by physician to improve the accuracy of standard error.

All data analyses were conducted using Stata 16.1 software (StataCorp LLC, College Station, Texas), and all figures were created in GraphPad Prism version 8.0 for Mac (GraphPad Software, La Jolla, California).

RESULTS

The final dataset consisted of 44,654 items used by 9 interventional radiologists (6–27 years in practice; mean, 16 years)

Table 1. Absolute Case Volume by Interventional Radiology and Procedure Category

	IR1	IR2	IR3	IR4	IR5	IR6	IR7	IR8	IR9	
Abscess drainage	19 (4.5)	30 (7.1)	44 (10.5)	54 (12.9)	38 (9.0)	38 (9.0)	58 (13.8)	102 (24.3)	37 (8.8)	420
Internal-external biliary drainage	7 (7.7)	11 (12.1)	17 (18.7)	9 (9.9)	11 (12.1)	11 (12.1)	2 (2.2)	2 (2.2)	11 (12.1)	91
Cholecystostomy	9 (6.9)	12 (9.2)	23 (17.6)	5 (3.8)	21 (16.0)	13 (9.9)	15 (11.5)	27 (20.6)	6 (4.6)	131
Nephrostomy	6 (5.2)	11 (9.6)	17 (14.8)	13 (11.3)	7 (6.1)	11 (9.6)	13 (11.3)	25 (21.7)	12 (10.4)	115
Gastrostomy	17 (8.5)	18 (9.0)	32 (16.1)	19 (9.5)	20 (10.1)	17 (8.5)	23 (11.6)	40 (20.1)	13 (6.5)	199
Gastrojejunostomy	2 (5.7)	4 (11.4)	2 (5.7)	3 (8.6)	6 (17.1)	2 (5.7)	6 (17.1)	6 (17.1)	4 (11.4)	35
Transjugular liver biopsy	13 (4.5)	24 (8.3)	51 (17.6)	37 (12.8)	38 (13.1)	22 (7.6)	38 (13.1)	36 (12.1)	30 (10.4)	289
UFE	-	-	-	10 (10.5)	-	-	10 (10.5)	75 (78.9)	-	95
Transarterial chemoembolization	14 (2.9)	-	-	45 (9.4)	82 (17.1)	76 (15.8)	116 (24.2)	-	147 (30.6)	480
Radioembolization preparatory angiography	6 (5.0)	-	-	-	-	30 (24.8)	14 (11.6)	-	71 (58.7)	121
Radioembolization administration	5 (3.4)	-	-	-	-	33 (22.8)	24 (16.6)	-	83 (57.2)	145
	98 (4.6)	110 (5.2)	186 (8.8)	195 (9.2)	223 (10.5)	253 (11.9)	319 (15.0)	323 (15.2)	414 (19.5)	**2,121**

Note–With volume as a percent of the total procedure typed in parentheses. Symbol '-' used for IRs that did not perform any cases of specific procedure in the time frame. The total number of cases for each procedure is represented in the far right column. The total number of cases for each IR is represented in the bottom row. IRs are listed in the order of increasing total number of cases.
IR = interventional radiology; UFE = uterine fibroid embolization.

Table 2. Summary Statistics for Procedures Analyzed, Including Mean, Minimum, Maximum, Standard Deviation and Coefficient of Variation in Cost per Case Across Physicians

Procedure	Mean cost ($)	Minimum cost ($)	Maximum cost ($)	SD ($)	CV (%)
Transjugular liver biopsy	749	707	817	37	4.9
UFE	1,251	1,145	1,389	103	8.3
Abscess drainage	283	255	332	24	8.5
Gastrostomy	453	379	514	47	10.3
Cholecystostomy	251	215	338	42	16.9
Transarterial chemoembolization	1,795	1,361	2,161	304	17.0
Nephrostomy	485	375	688	110	22.7
TARE preparatory angiography	2,183	1,646	2,758	546	25.0
Internal-external biliary drainage	573	452	916	145	25.3
Gastrojejunostomy	528	362	789	140	26.5
TARE administration	3,972	1,638	6,098	2,250	56.6

Note– Procedures listed in increasing order of CV. Cost in US$.
CV = coefficient of variation; SD = standard deviation; TARE = transarterial radioembolization; UFE = uterine fibroid embolization.

for 2,121 procedures across 11 procedure categories. Table 1 summarizes the procedure categories and the number of cases performed by each interventional radiologist over the 2-year time frame. While all interventional radiologists performed the percutaneous procedures, transarterial therapies were conducted by a subset of the physicians. As detailed in Table 1, the total number of procedures per procedure category varied widely. De novo gastrojejunostomy catheters accounted for the fewest total procedures (n = 35 cases), with a median of 4 procedures per physician (range, 2–6). In comparison, transarterial chemoembolization accounted for 480 procedures (range, 14–147 procedures; median, 79 per physician).

Table 2 summarizes the variation in spending among the 9 interventional radiologists for each of the 11 procedure categories. The SD for cost per case varied by procedure category, ranging from US$24 (abscess drain placement) to US$2,250 (radioembolization administration). One procedure category (transjugular liver biopsy) had a >5% CV, and 7 of the 11 procedure categories had a >15% CV. CV was used to compare relative variation among procedures as SD was influenced by the mean cost of the procedure, as demonstrated by UFE. UFE had a relatively high degree of absolute variation with an SD of US$103. However, relative to the mean US$1,251, the variation was lower than that of other procedure categories with a CV of 8.3%. Thus, while the degree of variation across physicians was not as great as it was for other procedures, its absolute magnitude was large.

To identify the drivers of variation for procedures with relatively standardized, reproducible procedural steps, 2

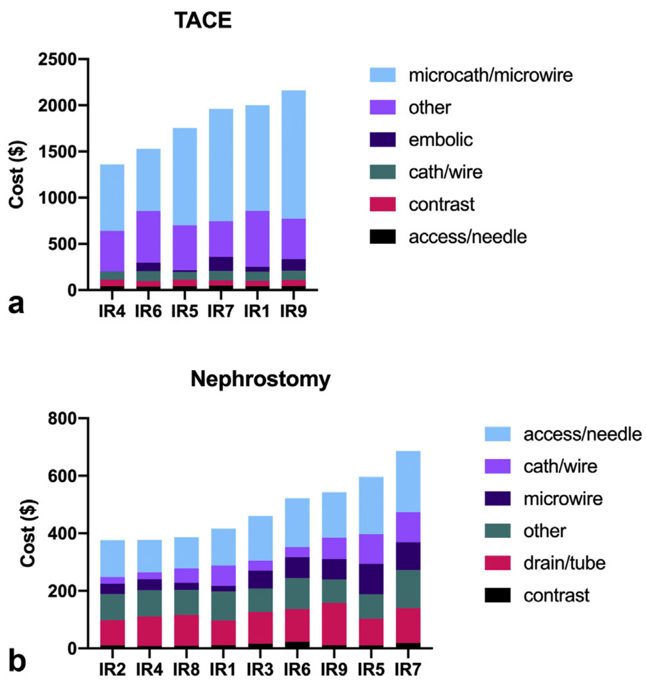

Figure 1. Total costs stacked by item category for procedure type: (a) transarterial chemoembolization and (b) nephrostomy catheter placement. The order of stacking from the lowest standard deviation within an item type to the highest; the order of bars from the lowest spending interventional radiology to the highest. The other category generally included syringes, saline, trays, and drapes.

high-volume procedure categories with high CV were selected for further analysis: transarterial chemoembolization and nephrostomy. Figure 1 provides a graphic display of the broad categories of expendable used by each physician. The graphs demonstrate that while most items were equivalent across physicians, a selected group of personal-preference items generated a high degree of variability and were the key drivers of variation in physicians' total spending. For example, the proportion of spending on commodity items, such as access needles and sheaths, ranged between 2% and 3% for transarterial chemoembolization, while that for microcatheters and microwires ranged from 44% to 64%. Similarly, for nephrostomy, expenditure on iodinated contrast was between 2% and 4%, while catheters and wires accounted for 6%–17% of the physician's total expenditure per procedure.

Finally, linear regression between case volume and mean cost by physician for each procedure category revealed that 5 categories (abscess drainage, transarterial chemoembolization, liver transjugular biopsy, and TARE preparatory angiography and administration) had a positive correlation and 6 (internal-external biliary drainage, cholecystostomy, gastrojejunostomy, gastrostomy, nephrostomy, and UFE) had a negative correlation, although no coefficient was statistically significant. The slopes of the fitted lines ranged between -18 (internal-external biliary drainage) and 55 (TARE administration) (Fig 2). Linear regression of the pooled model with procedure category as the second independent variable and data clustered by physician yielded a positive coefficient of 8.02 with a P value of.058; however, this was primarily driven by TARE administration. Pooled linear regression, excluding TARE administration data, yielded a nonsignificant coefficient of 1.34 (P =.584).

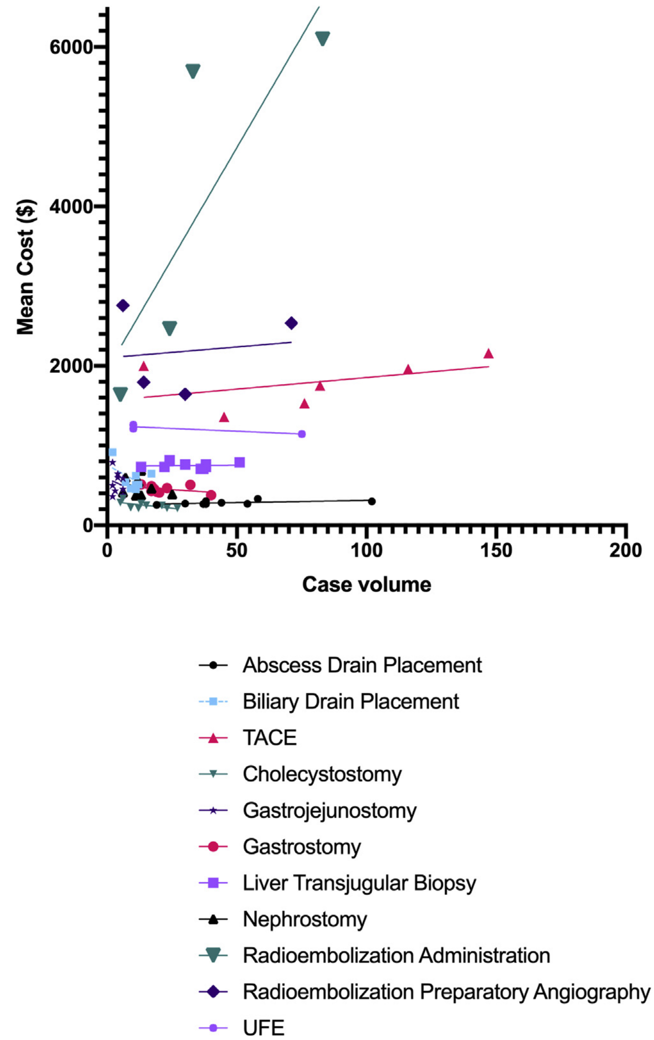

Figure 2. Mean cost over the total number of cases for each physician with linear regression by procedure category.

DISCUSSION

Physician-level variation is pervasive in medicine (7). Prior studies have focused on large scale geographic variations and healthcare outcomes (2,4,5). This study focuses on microcosm, analyzing the financial impact of individual physician preferences at a grassroots level. The current data indicate that even for common IR procedures performed at a single institution with experienced interventional radiologists, a high degree of inter-physician variation exists within each procedure category.

While individual practice patterns are commonplace, these data indicate that physician-driven preferences substantially impact the nonlabor cost borne by the institution. This is of particular significance for high-cost expendable items. The data showed that a few high-cost, expendable items were the main drivers for the cost variation. For example, physician microcatheter preference drove a cost variation for transarterial chemoembolization. The pattern held for simple procedures, such as de novo nephrostomy catheter placement, where the choice of wire(s) resulted in a 2-fold increase in spending by the highest spender when compared with the lowest spender. Thus, even moderate variation in expendable supplies can generate large variation in absolute spending in high-volume centers, leading to increased nonlabor costs.

The regression of the mean cost on case volume while controlling for procedure and clustering by physician yielded a positive coefficient, with a P value of.058. Upon removal of TARE administration data, the regression coefficient decreased to 1.33, with a P value of.584. This suggests that the positive relationship was driven by TARE administration data and that the true correlation between the mean cost and the case volume may be neutral. A more in-depth analysis to understand the root cause of this correlation is required to interpret these findings and is outside the scope of this study.

These results have significant implications for interventions promoting value-based care in IR when the value is defined as the outcome of a particular procedure or treatment divided by its cost. Under value-based care, an improvement in outcome (eg, improved survival), decreased cost, or both would optimize the value. While labor costs are considerable, nonlabor costs that include expendable supplies account for a substantial share of the total cost. In a 2014 study that explored the operational expense of transarterial chemoembolization, the authors found that 62% of the costs were attributed to expendable supplies at their academic institution (4). Similarly, Ahmed et al analyzed the institutional expenses for selective, cone-beam assisted, transarterial chemoembolization and reported a mean cost of US$2,806 for expendable items, a 36% share of total costs (3). The findings from these studies and the data reported herein suggest that expendable items and devices substantially contribute to the overall cost. More importantly, physician preference plays a central role in determining expenses from a hospital's cost perspective. Therefore, optimizing cost-efficiency by carefully examining nonlabor expenses without compromising patient outcomes may be the first step in modifying physician behavior.

Studies on device selection have previously shown significant cost savings through standardization. A 2015 study found a decrease in cost per laparoscopic appendectomy from US$844 to US$305 simply by implementing a uniform doctor's preference card with devices selected based on cost, availability, and utility (13). Another study found savings of US$8 million by utilizing a physician-driven technology assessment committee that reviewed new products, standardized some products, and decreased the costs of physician preference items (14). Simply informing physicians about the costs and alternatives of shunts and dural substitutes led to a mean annual cost savings of US$234,175 (12). The evidence presented in this study suggests that the standardization of high-cost, high-variation devices would allow substantial cost savings.

While this study provides perspective on inter-physician variation, it has limitations. The data solely look at the cost rather than the case complexity and patient outcomes. Patient and procedural complexities may depend on the use of multiple products within a category. Only procedures with standard, generalizable techniques and without missing data were included to minimize outliers and allow meaningful comparisons. Further, 2 procedures, despite reproducible, had to be excluded due to missing data. The data itself were limited to 2 years and had limitations inherent to a retrospective dataset, especially since device costs borne by a hospital vary from institution to institution. Finally, this analysis primarily focused on physician preferences' financial implications that did not account for other decision drivers, such as decreased procedural time, radiation dose, or patient safety. As with all healthcare analytics, procedural and patient outcomes are critical, and further studies should consider these factors. Despite these limitations, this study establishes the existence of cost variation within groups independent of the actual costs.

In conclusion, these findings suggest that there may be a high degree of practice variation in IR. Identifying these variations, addressing them through physician education, and creating standard guidelines may represent a path to progress toward cost-efficiency.

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