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Does healthcare system device volume correlate with price paid for spinal implants: a cross-sectional analysis of a national purchasing database

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ABSTRACT

Objectives Amid continuously rising US healthcare costs, particularly for inpatient and surgical services, strategies to more effectively manage supply chain expenses are urgently necessary. Across industries, the 'economy of scale' principle indicates that larger purchasing volumes should correspond to lower prices due to 'bulk discounts'. Even as such advantages of scale have driven health system mergers in the USA, it is not clear whether they are being achieved, including for specialised products like surgical implants which may be more vulnerable to cost inefficiency. The objective of this observational cross-sectional study was to investigate whether purchasing volumes for spinal implants was correlated with price paid.

Setting USA.

Participants Market data based on pricing levels for spine implants were reviewed from industry implant price databases. Filters were applied to narrow the sample to include comparable institutions based on procedural volume, patient characteristics and geographical considerations. Information on the attributes of 619 health systems representing 12 471 provider locations was derived from national databases and analytics platforms.

Primary outcome measure Institution-specific price index paid for spinal implants, normalised to the national average price point achieved.

Results A Spearman's correlation test indicated a weak relationship between purchasing volume and price index paid ($\rho=-0.35$, $p<0.001$). Multivariable linear regression adjusting for institutional characteristics including type of hospital, accountable care organisation status, payer-mix, geography, number of staffed beds, number of affiliated physicians and volume of patient throughput also did not exhibit a statistically significant relationship between purchasing volume and price index performance ($p=0.085$).

Conclusions National supply chain data revealed that there was no significant relationship between purchasing volume and price paid by health systems for spinal implants. These findings suggest that factors other than purchasing or patient volume are responsible for setting prices paid by health systems to surgical vendors and/or larger healthcare systems are not negotiating in a way to consistently achieve optimal pricing.

Strengths and limitations of this study

- ► This study illuminates critical healthcare supply chain issues, an area with international relevance that has historically lacked publicly available data in the peer-reviewed literature.
- ► Minimal information on the negotiation process or other factors were available, and have the potential to confound the final pricing at each institution.
- ► This study draws from a large sample representing hundreds of healthcare institutions with thousands of clinical sites from across the USA.
- ► This study only addressed implants used for a single set of specialised procedures; future studies can help validate the observations made here in other surgical settings.
- ► The findings can inform clinicians, administrators, policy makers and industry—both in the USA and beyond—on the factors that impact supply chain efficiencies in healthcare.

BACKGROUND

In the US healthcare system, expenditures have increased at a rate two to three times the wage growth and costs are the highest per capita in the world.[1 2] Between direct costs and indirect wage reductions, the average American spends >$16 000 annually on healthcare.[3] Hospital costs represent almost a third of total healthcare costs, and growth in hospital expenditures continues to accelerate annually.[4]

Expenses associated with medical procedures are an important and expanding cost centre for the healthcare system, and costs associated with procedures are increasing faster than the rate of inflation.[5] Equipment constitutes a meaningful fraction of the nearly $200 billion spent on procedures annually; some studies have found that medical devices represent nearly a quarter of US hospital operating costs.[6–8] However, variability in prices paid for medical products

remains common and considerable;[9] costs associated with devices used for treatment of similar injuries can vary up to sixfold in this country.[10–13] Medical devices—including those used for spinal surgeries which, according to the Agency for Healthcare Research and Quality, are the 'most costly principal OR procedure' in this country at more than $14 billion annually—thus represent a critical target for healthcare cost control.

Hospital efforts to reduce these costs include mergers to leverage advantages of scale.[14–16] In common business parlance, the 'economy of scale' principle dictates that larger purchasing volumes correspond to lower purchase prices due to 'bulk discounts'. Economies of scale refer to the supply chain cost advantages associated with scale of operation, in which infrastructural costs can be 'spread out' over larger volumes of supplies purchased. Such is the case with wholesale, rather than off-the-shelf, purchasing. Economies of scale can lead to decreased marginal costs and thus can provide a competitive advantage for companies with well-designed supply chains across many industries.[17 18]

Indeed, there has been a clear trend of increased health system consolidation since 2000, with a significant uptick following the Affordable Care Act in 2010.[15] The percentage of physicians in practices owned by hospitals grew by more than 70% between 2012 and 2018, totalling nearly 170 000 in 2018 (44% of all licensed physicians in the country).[19]

However, there remains a paucity of evidence related to the success of hospital supply chains in achieving optimal pricing consistent with economies of scale.[6] Specialised equipment can present a particular challenge for achieving economies of scale, since these goods have historically been considered less commodifiable than mainstream equipment.[20] Lack of commodifiability can make best practices such as vendor consolidation—which has been shown to reduce costs by 20% or more—unfavourable, infeasible, or both.[21–23] Additionally, lack of commodifiability can lead to wide price variation: prices for spinal implants in particular can range fourfold to sevenfold, depending on the location, make and use case for the given device.[24 25] Such wide ranges of pricing imply that specialised devices like spinal implants may be susceptible to price distortion from non-objective factors; in cases where purchasing standardisation has been adopted, savings of between 25% and 40% have been observed for spinal implants specifically.[23 26] Perceptions of non-commodifiability may also leave expenditures related to specialised equipment more vulnerable to clinician choice, which has been shown to introduce significant variability into supply chain costs.[8]

In short, while many factors in the negotiation process beyond volume alone may affect the price of (specialised) medical products, the strength of the relationship between volume and price remains empirically unclear. This study evaluated the relationship between spinal implant purchasing volume and price paid by healthcare systems in a national market database, hypothesising that higher levels of purchasing volume correlate with lower prices paid.

METHODS

Compilation of the sample

Information on health system purchasing volume, and price performance was derived from Vizient's national supply analytics platform and anonymised before access. Hospital demographic information was obtained with permission from Definitive Healthcare (Framingham, Massachusetts, USA), a software company that provides data on healthcare providers.

To compare spinal implant volume and pricing among healthcare organisations (HCOs), blinded data were aggregated from a nationally representative sample of 619 Vizient member organisations representing 12 471 provider locations between 1 April 19 to 31 March 2020. The data were then filtered to include only HCOs with purchasing data on spinal implants, yielding a total of 105 organisations. Variables of interest included: annual category spend on spinal implants, operating beds, HCOs with an annual category spend above $100 000 and more than 300 operating beds. Each covariate of interest was subsequently divided into subcategories. Three outlying institutions had annual category expenditures greater than $30 million and were excluded. The dependent variable, price index, was constructed by normalising spinal implant purchase transactions of varying size to assess relative price performance, reflecting the relative price performance of a given institution within the total sample.

Patient and public involvement

No patients or population groups were involved.

Data analysis

A Spearman's correlation test evaluated the correlation between implant purchasing volume and price as well as purchasing volume and price quartile. Multivariable regression evaluated the association between annual purchasing volume and price index paid after adjusting for hospital parameters statistically defined as categorical covariates. Collinearity was assessed and all variables in the model had variable inflation factors below 10. Analyses were completed in RStudio V.1.1.456 (Boston, Massachusetts, USA) using a two-sided level of significance of 0.05.

RESULTS

The sample set included 102 institutions from across the USA, and characteristic information on the institutions in the sample were collected (table 1).

The purchasing volume for spinal implants ranged from $0.2 million to $27.1 million, with a median of $3.7 million. The relative price index ranged from 5.8 to 90.2, with a mean of 54.7 (±19.7). A Spearman's

Table 1 Institutional characteristics of the sample (created by the authors)

Facility type	Number	Percentage
Children's hospital	9	8.8%
Health system	54	52.9%
Acute care hospital	39	38.2%
Geographical region		
Mid-Atlantic	8	7.8%
Midwest	39	38.2%
North-East	6	5.9%
North-West	5	4.9%
South-East	24	23.5%
South-West	9	8.8%
West	11	10.8%
Medicaid %		
0%–5%	15	14.7%
6%–8%	23	22.5%
9%–13%	24	23.5%
14%–26%	20	19.6%
27%–48%	6	5.9%
N/A	14	13.7%
Staffed beds		
<2000	82	80.4%
2000–3499	20	19.6%
Outpatient visits		
<149 999	22	21.6%
150 000–249 999	16	15.7%
250 000–499 999	20	19.6%
>500 000	44	43.1%
Inpatient surgeries		
<10 499	58	56.8%
10 500–19 499	44	43.2%
Discharges		
<19 999	42	41.2%
20 000–59 999	34	33.3%
>60 000	26	25.5%

correlation test between purchasing volume and price index across these 102 institutions indicated a correlation coefficient (ρ) of −0.35 (p<0.001) (figure 1).

Subgroup analysis by quartile indicated a median price index of 62.8 (IQR=30.5) for the first quartile, with spend for this quartile ranging from $0.2 million to $1.4 million. The second quartile had a median price index of 59.2 (IQR=40.0), with total spend between $1.4 million and $3.7 million. The third quartile had a median price index of 48.3 (IQR=20.6) with total spend between $3.7 million and $8.1 million. The fourth quartile had a median price index of 48.3 (IQR=18.1), with total spend ranging from $8.1 million to $27.1 million. Institutions in the first quartile of total spend had significantly higher price indices than institutions in the third quartile (p=0.03) and fourth quartile (p=0.03) (figure 2).

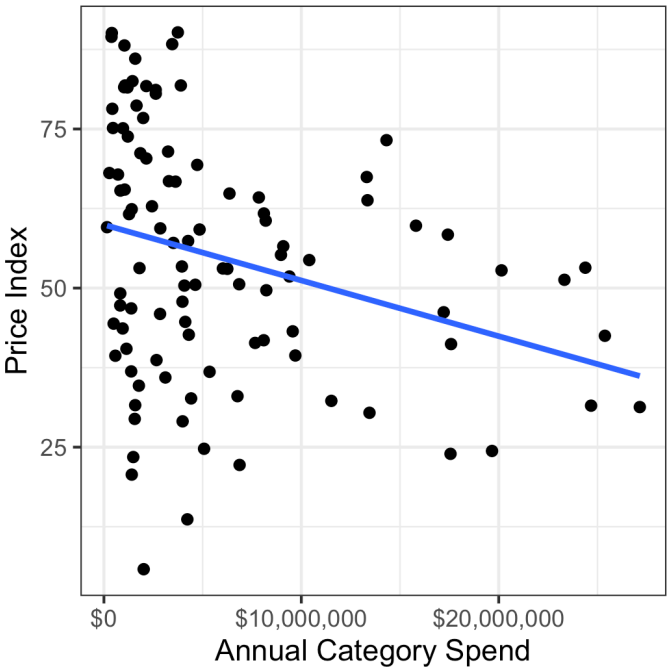

Figure 1 Correlation between total healthcare organisation (HCO) spend and price index paid for spinal implants (created by the authors).

On multivariable analysis, the price index was compared with annual purchasing volume adjusted by the characteristics included in table 1. In this adjusted model, the strength of the relationship between annual category spend and price index was not significant (p=0.085). Of all institutional characteristics considered, a statistically significant association with decreased price index was observed for institutions located in the south-east region compared with the mid-Atlantic region (p=0.007). Institutions with annual outpatient visits between 150 000 and 499 999 were associated with a statistically significant increase in price index compared with institutions with 0 to 149 999 outpatient visits (p=0.026–0.044). No other institutional characteristics exhibited a statistically significant association with increased or decreased price index (table 2).

DISCUSSION

Statement of the principal findings

These findings demonstrate that even at high levels of purchasing volume, healthcare systems across the USA do not appear to be capturing proposed economic advantages related to price reduction associated with scale for spinal implants. The relationship between purchasing volume and price index was statistically significant but nominally weak on unadjusted linear regression; the statistical significance disappeared after inclusion of institutional characteristics in the model. These findings suggest that price index for spinal implants is not

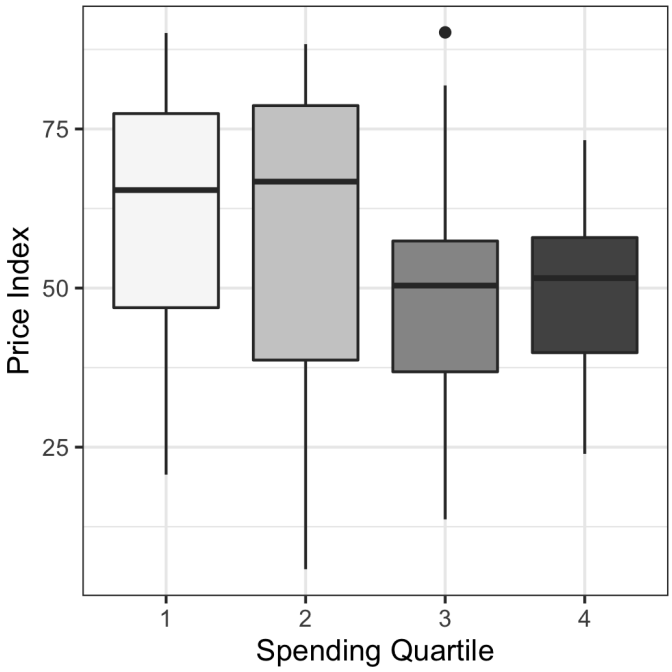

Figure 2 Range of healthcare organisations (HCOs) spinal implant price performance, stratified by quartile of total spend (created by the authors).

meaningfully determined by purchasing volume after adjustment for institutional characteristics.

When examining the price paid by total spend stratified into quartiles, while the first quartile of spend had significantly higher price indices than the third and fourth quartiles, no other statistically significant relationships were observed. This suggests that category spend below a threshold of $1.4 million may lead to higher prices than category spend $3.7 million and above—however, only when no other covariates are considered.

After adjustment for various institutional characteristics, the relationship between purchasing volume and price index was not statistically significant. This suggests that after accounting for institutional characteristics, the theoretical price advantages of scale no longer materialised in this sample. The only institutional characteristics which exhibited a statistically relevant relationship with price index were geographical location in the south-eastern USA and intermediate levels of outpatient clinic visits. These results, demonstrating no volume-price relationship, differ from previous single-year studies that performed pure volume-price correlation analyses in smaller samples without adjusting for any hospital characteristics.[25] As this is the first known quantitative evaluation of economies of scale in hospital supply chains that included institutional characteristics, the observation that pricing advantages disappeared after adjustment for institutional features may be relevant for future discussions around cost reduction in this country's healthcare system.

As for the influence of geographical location on price, previous analyses by the Centres for Medicare and Medicaid Services have found that pricing of surgical implants can vary considerably by region.[27] One major consideration in price paid for implants is the relative market concentration of surgical providers, which influences the negotiating power of healthcare institutions with device vendors.[28] Analyses as of 2016 indicated that the South-East is relatively concentrated compared with other regions, but there may be additional local factors—like those related to the availability of spinal procedures specifically—leading to disproportionate negotiating power of health institutions in this region to drive down implant prices.[29]

The number of annual outpatient clinic visits provides a proxy estimate for overall institutional size. Higher number of annual outpatient visits suggests that a given institution has a larger regional presence, and therefore, in theory, greater bargaining power with suppliers.[17] Thus, it would follow theoretically that an institution with a lower number of outpatient visits would have relatively lower negotiating power, and therefore, be subjected to higher prices. However, it is less clear why the level of outpatient visits—but not the level of inpatient surgeries

Table 2 Multivariable regression comparing annual category spend to organisational characteristics (created by the authors)

Variable	Level	Estimate	P value
Annual category spend		–9.7E-07	0.085
Hospital type	Children's hospital	0.00	–
	Health system	3.55	0.770
	Short-term acute care hospital	–4.64	0.687
Geographical region	Mid-Atlantic	0.00	–
	Mid-West	–12.65	0.091
	North-East	–16.65	0.118
	North-West	–19.64	0.069
	South-East	–22.71	**0.007**
	South-West	–9.34	0.307
	West	–11.18	0.254
Medicaid %	6%–8%	9.81	0.118
	9%–13%	9.94	0.129
	14%–26%	2.75	0.674
	27%–48%	14.35	0.153
	Unknown	–3.92	0.699
Staffed beds	>2000	1.34	0.877
Outpatient visits	150 000–249 999	14.85	**0.026**
	250 000–499 999	13.90	**0.044**
	>500 000	–4.77	0.521
Inpatient surgeries	10 500–19 499	–3.39	0.632
Discharges	20 000–59 999	–1.58	0.786
	>60 000	6.70	0.543

or discharges—would diminish the prices paid for spinal implants. Previous analyses have found that, in fact, hospital system scale is not a reliable predictor of hospital costs, including those paid for surgical implants.[15 30]

Relation to general context of the topic

Taken together, the findings on multivariable analysis suggest that between institutions with similar characteristics, annual purchasing volume again is not a statistically significant determinant of price index for spinal implants. This agrees with previous analyses that find increasing scale alone is not a consistent predictor of diminishing price paid.[15 30] Indeed, pioneering work by Robinson and colleagues has shown that, for total hip replacements, 60% of implant cost variation was related to within-hospital variation not attributable to patient or hospital characteristics.[31]

There may be multiple potential reasons for the results observed in this analysis.[32 33] One factor for consideration driving these results relates to the number of vendors maintained by the health system, which may play a role in the negotiating power of health systems. The number of vendors maintained by health systems may be related to surgeon preferences for specific devices.[34] Previous studies have found that price savings for 'physician preference items'—specialised products 'where doctors' usage decisions are relatively insensitive to price'—are typically higher than interchangeable commodity goods.[35] This implies that product categories with specialised devices produced by numerous vendors, each with unique and defining characteristics, may be more vulnerable to cost variation due to reasons beyond purchasing scale alone.

Data analysed in this study show that the mean number of suppliers in the spinal implant category is 16, while the maximum number of suppliers was 47. Surgeon preference for particular vendors or implants may adversely affect the health system's ability to negotiate, by 'spreading thin' overall volume across many vendors. Thus, the large number of surgical vendors may squander potential cost and/or negotiating advantages conferred by bulk purchasing.[36] Additionally, surgeon preference can lead to contracts for more expensive implants.[37]

A second area of consideration relates to the use of local negotiations as opposed to group purchasing organisations (GPOs).[38] Participation in a GPO may provide a strategy towards improving buyer power in contract negotiation by pooling together purchasing volume across health systems: some studies suggest that cost savings generated through GPO participation range as high as 18%.[38–42] Indeed, in recent years, health systems have sought out these advantages: as of 2014, 98% of health systems participated in GPOs for some portion of their purchasing needs.[41]

However, even as the majority of health systems participated in GPOs for some of their purchasing needs, locally led negotiation remains common: according to the data here, 80% of the spinal implant volume was locally negotiated. 'Bargaining ability'—defined by Grennan as a 'firm-specific capability' in which there is significant heterogeneity across hospitals that varies over time with learning and/or organisational change—is pivotal for cost determination across business sectors; previous studies on healthcare specifically have found that bargaining abilities explain over three-quarters of variation in prices paid.[43]

Implications for clinicians, administrators and future research

The findings in this study suggest that while there may be a role for locally led negotiation for optimal value creation—negotiation led at the local level may render cost savings when conducted in a principled and clinically centred way—maximising savings for categories of specialised products may not be realised through local purchasing volume alone, in lieu of strategic negotiation and/or GPO participation.[37 41 44–46] Thus, whether HCO participation in regional and/or national negotiating efforts through GPOs can achieve better purchasing value for spinal implants—and other devices—represents an important area for additional study.[38]

Overall, several opportunities exist to help capture potential cost savings associated with economies of scale. One such strategy involves expanding the body of evidence on the design and maintenance of health system supply chains, including consolidating or retaining additional vendors. Studies have demonstrated that, when presented with low-cost alternatives compared with previously used high-cost equipment, the majority of orthopaedic surgical staff report being comfortable with such a cost-saving swap.[47] Lower-cost alternative devices, even in lieu of a brand name, have demonstrated non-inferior outcomes in procedures such as total knee arthroplasty.[48] There may also be risk-reduction opportunities in simplifying the surgical supply chain, which is itself a common goal of high-reliability organisations.

A second strategy relates to optimising institutional relationships with GPOs in a manner that maximises cost savings. A third strategy would be increasing cost transparency with surgeons who are using these implants. Surgeons and partnering departments should be given data on outcomes and costs and included in a collaborative, informed decision-making process when it comes to implants and surgical instruments.[49]

Weaknesses of the study

Limitations of this study include factors related to the nature of a database study. The databases used here had minimal information on the negotiation process or other factors that may have confounded the final pricing at each institution. Such factors could include institutional prestige/branding, local HCO market density for specialised procedures, the presence of national clinical leaders, pre-existing relationships between institutional persons and vendors, or robustness of internal supply chain departments among other considerations. The databases also contained limited information on relative regional presence of a given institution, in comparison

to peer competitors and local market density; since the data were anonymised prior to analysis, it was not possible to enumerate these details further. With this question in mind, we picked thresholds of visit volume that we believe would represent large regional presence. While it is possible in urban centres with multiple hospitals providing specialised procedures that high visit volumes may not completely reflect regional presence, we postulate that in most regions the thresholds chosen here will be approximate for regional presence accurately. Additionally, while numerous measures of hospital size and patient care volume were used here, information about the number of paediatric spine surgeries was not specifically available. While it is likely that overall hospital size corresponds with volume of paediatric spinal surgeries, it should be noted that specialty centres that focus on such procedures may provide an exception to this rule. Also, because of the nature of price indices, it is possible that large relative differences in price index reflect small absolute differences in prices, or vice versa. Furthermore, given price and volume are not, in all cases, completely independent—for example, due to the nature of insurance reimbursement structures in this country, lower volume institutions may pay higher prices for devices if they believe these prices will be covered regardless—the potential for statistical anomalies such as reverse causality cannot be completely ruled out in this analysis. Future studies can help parse the relative independence and directionality of this volume-price relationship. Lastly, this study only addressed implants used for a single set of procedures, and thus, future studies can help validate the observations made here in other surgical settings.

CONCLUSION

In conclusion, this analysis of industry supply chain data revealed minimal correlation between healthcare system purchasing volume and price for spine implants. These findings suggest that factors other than purchasing volume are responsible for setting payment prices and/or larger healthcare systems may not be negotiating successfully to achieve optimal pricing or 'bulk discounts'. In the setting of continuously rising healthcare costs, particularly for inpatient and surgical services, strategies to reign in excessive supply chain expenses are urgently necessary. Future research on the structure of supply chains and the factors correlating with prices paid can help health systems realise opportunities to optimise their design to promote low costs while preserving high levels of patient care.

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