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Impact of Processes of Care Aimed at Complication Reduction on the Cost of Complex Cancer Surgery

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Background and Objectives: Health care providers add multiple processes to the care of complex cancer patients, believing they prevent and/or ameliorate complications. However, the relationship between these processes, complication remediation, and expenditures is unknown.
Methods: Data for patients with cancer diagnoses undergoing colectomy, rectal resection, pulmonary lobectomy, pneumonectomy, esophagectomy, and pancreatic resection were obtained from hospital and inpatient physician Medicare claims for the years 2005–2009. Risk-adjusted regression analyses measured the association between hospitalization costs and processes presumed to prevent and/or remedy complications common to high-risk procedures.
Results: After controlling for comorbidities, analysis identified associations between increased costs and use of multiple processes, including arterial lines (4–12% higher; $P < 0.001$) and pulmonary artery catheters (23–33% higher; $P < 0.001$). Epidural analgesia was not associated with higher costs. Consultations were associated with 24-44% ($P < 0.001$) higher costs, and total parenteral nutrition was associated with 13–31% higher costs ($P < 0.001$).
Conclusions: Many frequently utilized processes and services presumed to avoid and/or ameliorate complications are associated with increased surgical oncology costs. This suggests that the patient-centered value of each process should be measured on a procedure-specific basis. Likewise, further attention should be focused on defining the efficacy of each of these costly, but frequently unproven, additions to perioperative care.
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KEY WORDS: **cancer; cost analysis; surgery; process of care**

INTRODUCTION

In the course of treating cancer patients hospitalized for surgical procedures, health providers variably utilize multiple processes of care. Processes of care, defined by the Centers for Medicare and Medicaid Services (CMS) as a "series of inter-related activities undertaken to achieve objectives," are believed to be integral components of safe and effective care received by surgery patients, based on a belief that they prevent or ameliorate the impact of complications [1]. For the most part, these processes are optional and under the control of the surgical and anesthetic teams. The CMS-monitored processes are an important component of treatment to study, because they are readily quantified and more accepted by providers as indicators of their individual quality compared to outcome measures attributable to patient characteristics which are outside of provider control [2,3].

Within the oncology field, surgery is often a primary component of treatment and in many cases the only treatment modality that offers a chance for cure. The episode of oncologic surgery care includes many embedded processes of care. Despite frequent use, the efficacy of many processes that surgical teams employ is unproven. Nonetheless, health care providers assume that they represent timely and effective interventions that avoid complications and achieve better patient outcomes through safer and more rapid recoveries [4,5]. Furthermore, by avoiding and/or ameliorating complications, they are assumed to be cost effective.

Combined, the components of cancer surgery can be very costly. The direct costs of medical care for cancer reached $86.6 billion in 2009 [6]. Looking forward, the National Cancer Institute estimates that cancer-specific care costs will grow more quickly than overall medical expenditures [7].Within surgical oncology, however, there is little consensus on whether the addition of processes of care raise expenditures (via increased resource utilization) or lower costs (via increased efficiency and lower postoperative length of stay). And while previous literature has found that surgical complications raise costs for cancer surgery [8–11], much less is known about which services to remediate complications are the most costly [9,12,13]. Delivering cost-effective cancer surgery requires better knowledge of how individual processes influence the overall cost of inpatient care, and which strategies used to prevent or ameliorate complications are the most costly.

Only one previous study has examined the relationship between these processes of care and patient mortality, finding that the differences in process utilization did not drive the volume-mortality relationship [14]. To date, no studies have examined the relationship

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between these same processes and costs of care using administrative or more detailed clinical data. Given the lack of correlation between processes of care and mortality, measurement of the association between processes and costs may provide valuable information on the denominator of the value equation that has been proposed by Michael Porter as a more patient-centric version of the traditional definition of value (Porter's Value=Patient Outcome/Cost Across the Episode of Care) [15]. Although individual processes cannot explain all of the cost differentials in cancer surgery, given how little we know about cost drivers, the proposed analysis represents an important first step in examining these relationships [16].

MATERIALS AND METHODS

The analytical methods used were similar to our previously published study of the association between surgical complications and costs [17]. Patient-level Medicare Claims data from all 50 states for the years 2005–2009 were used to analyze the relationships between processes of care and costs for six cancer resections: colectomy (N = 140,146), rectal resection (N = 24,283), pulmonary lobectomy (N = 48,224), pneumonectomy (N = 2,808), esophagectomy (N = 3,717), and pancreatic resection (N = 11,668). The 100% MedPAR files and Carrier files were merged. ICD-9-CM diagnosis and procedure codes were used to confirm that the cancer indication matched the resection type as a requirement for inclusion in the study (Table SI in the supplement) [18].

Costs

The MedPAR data provided detailed information on hospital charges by revenue center for each discharge. Charges were adjusted by the All-Urban Consumer Price Index to reflect 2005 dollars. Following previously published methodology, costs for each hospital stay were estimated by multiplying the reported patient charge by the hospital's cost-to-charge ratio in the same year [18–23]. Next, all physician billings to Medicare for the patient's hospital stay were identified in the Carrier claims files and summed to represent physician costs associated with the admission. Lastly, hospital and physician costs were summed to calculate the explanatory variable of total costs per entire inpatient stay.

Processes of Care and Services Used to Prevent and/or Treat Complications

The processes of care and services used to avoid and/or ameliorate complications that were included in these analyses focused on those common to high-risk procedures and those potentially related to morbidity and mortality. Following methodologies previously used to assess the volume-process relationship in high-risk cancer surgery [14,24], these services were identified by ICD-9-CM procedure codes and CPT codes in the claims data (Table SII in the supplement). Birkmeyer et al. developed this methodology by consulting the literature including a comprehensive review of hospital safety practices and expert clinicians, determining which forms of care could be defined using claims data, and performing pilot analyses to develop and test the coding [14,25]. Each service was classified as intraoperative (pulmonary artery catheter, arterial line, central venous catheter [independent of pulmonary artery catheter], epidural analgesia, packed red blood cell transfusion/auto transfusion), or postoperative (critical care consultation, inpatient consultation, total parenteral nutrition, daily epidural management).

Hospital, Surgeon, and Patient Characteristics

Hospital volume was constructed by summing the total number of operations performed by each hospital in each year for each of the six cancer resections. Surgeon volume was calculated in the same manner.

Additional hospital characteristics obtained from the American Hospital Association Annual Survey of Hospitals and included in the analysis were the nurse-to-patient ratio and indicator variables for complex medical technologies which are more likely to be present at high-volume hospitals (CT scanner, magnetic resonance imaging, positron emission tomography). In Medicare cost reports, these equipment costs are allocated to patient cost centers used by cancer surgery patients, and therefore, may be associated with higher costs per patient. In addition, hospital fixed effects were used in the analysis to control for observed and unobserved factors that remained constant across the sample period. For statistical summary purposes, hospitals were identified as teaching or non-teaching and their geographical location was noted as a rural or urban area.

Patient-level demographics used for risk-adjustment included sex, age, race and income. To adjust for comorbidities, secondary diagnosis codes were used to construct indicator variables for the conditions comprising the Elixhauser comorbidity index [26]. Indicator variables were included for patients transferred from another hospital and urgent/emergent admissions. Cancer stage was measured using secondary diagnosis codes for nodal involvement and organ metastasis [27]. To adjust for disease-specific differences in procedure complexity and patient case-mix, indicator variables were also defined for particular operations and surgical approaches specific to each procedure. Operating time was measured as total hours claimed for anesthesia [14]. Procedure and tumor sites were defined based on previous studies of these operations that used ICD-9-CM procedure and diagnosis codes [27–32]. Subspecialty of the operating surgeon was identified using the Medicare Physician Identification and Eligibility Registry.

Statistical Analysis

Regressions were separately estimated for each cancer resection to assess the relationship between processes of care and the natural log of total costs. Similar to previously published statistical techniques, each cost regression was adjusted for all of the hospital, patient, and surgeon characteristics listed above—with the exception of teaching and rural indicators— and performed using panel data with year and hospital fixed effects (Table SIII in the supplement) [14,17,28,33,34]. Regressions were estimated using the xtreg command in STATA version 12.1 (STATA-Corp, College Station, TX) with specifications to provide robust standard errors to account for clustering of patient data within hospitals [17].

RESULTS

Patient Characteristics by Operation Type

Table I summarizes the patient characteristics for each procedure. Each of the procedures is relatively close to a 50/50 distribution by sex, except esophagectomy and pneumonectomy which tend to be performed on males. All of the procedures are performed primarily on white individuals. For each procedure, the oldest age group—those age 85 or older—are the least likely to have a procedure performed. Transfer patients make a small percentage of the patient cohorts. Few patients are urgent or emergent admissions, with the exception of colectomy which has close to 25% urgent/emergent admissions. The numbers of comorbidities are similarly distributed across all the procedures with over 2/3 of patients with 2 or fewer comorbidities.

Total Costs by Operation Type

Table II summarizes total hospitalization costs for each procedure. Esophagectomy demonstrated the highest with median costs of

TABLE I. Summary of Patient Characteristics by Surgical Procedure for Medicare Patients From 2005 to 2009

	Colectomy (N = 140,146) (%)	Pulmonary lobectomy (N = 48,224) (%)	Rectal resection (N = 24,283) (%)	Pancreatic resection (N = 11,668) (%)	Esophagectomy (N = 3,717) (%)	Pneumonectomy (N = 2,808) (%)
Sex						
Male	44.1	50.7	56.4	49.2	80.6	69.7
Female	55.9	49.3	43.6	50.8	19.4	30.3
Race						
White	87.9	91.3	89.3	88.6	94.3	91.3
Black	8.4	5.5	5.9	6.9	3.1	5.3
Other	3.7	3.2	4.8	4.5	2.6	3.5
Age						
65–74	33.6	54.0	45.5	52.2	62.3	67.0
75–84	44.5	41.8	42.0	42.5	34.9	31.2
85+	21.9	4.2	12.5	5.3	2.8	1.8
Transfer patient	2.0	0.5	1.1	3.6	1.2	0.9
Urgent/emergent admission	24.7	1.8	7.5	7.8	2.3	2.9
Number of comorbidities						
0	12.2	10.6	16.6	15.3	18.7	12.5
1	27.1	28.2	31.1	31.5	34.1	30.9
2	29.9	32.3	28.3	30.3	28.4	31.4
3+	30.7	28.8	24.1	23.0	18.8	25.3

$34,615. Rectal resection and colectomy had the lowest with median observed costs of $15,523 and $14,948, respectively.

Process of Care Utilization by Hospital Type

Overall rates of services for all cancer operations stratified by hospital characteristics (procedure volume, teaching status, and locale) are presented in Table III. Independent of procedure type, the overall utilization rates for the processes ranged from 1.68% for pulmonary artery catheters (PACs) up to 34.42% for arterial lines. Compared to low-volume hospitals, high-volume hospitals tended to have higher use of intraoperative processes. Teaching hospitals tended to utilize intraoperative processes more and postoperative processes, except daily epidural management, less often than their non-teaching counterparts. Urban hospitals had higher utilization rates than rural for all processes except transfusions.

Processes of Care by Operation Type

Table IV details the utilization of processes of care for prevention and remediation of complications by cancer surgery procedure type. Given the contemporary time period, utilization of PACs for non-thoracic procedures was higher than expected (1.1–8.7% of patients). Arterial lines were the most commonly used form of monitoring for all procedures except colectomy (16–88% of patients). CVCs were utilized in 18–26% of patients. Epidural analgesia utilization rates were very similar to those for daily epidural management suggesting that most patients who receive intraoperative epidural analgesia continue this into the postoperative phase of recovery.

TABLE II. Summary of Hospitalization Costs for Six Surgical Oncology Procedures Adjusted to 2005 Dollar Values

	Mean	Median	Min	Max
Colectomy	20,218	14,948	2,274	429,176
Pulmonary lobectomy	23,096	17,898	4,155	522,620
Rectal resection	20,169	15,523	2,349	201,246
Pancreatic resection	39,031	28,993	6,818	622,543
Esophagectomy	50,377	34,615	8,922	488,187
Pneumonectomy	27,912	19,978	6,225	295,048

Relationships Between Processes of Care for Amelioration of Complications and Cost of Care by Operation Type

Table V lists the cost coefficient estimates and two-sided *t*-statistics for the various forms of care. In many cases the association between individual services and total costs was observed to be significant and positive.

Intraoperative monitoring was significant at several levels. PAC use was associated with 24–33% higher costs for all six procedures. Arterial lines were associated with increased costs for colectomy, rectal resection and pancreatic resection ($P < 0.001$). CVCs were associated with 11–22% higher costs for all six procedures ($P < 0.001$). There was no significant increase in costs associated with epidural analgesia, but the data suggest that epidural anesthesia was associated with a 1% decrease in the costs of pulmonary lobectomy. There were mixed results for the use of blood product replacement, showing an increase in costs for colectomy, pulmonary lobectomy, and rectal resections but a decrease in costs for pancreatic resection and esophagectomy.

Regarding postoperative care, total parenteral nutrition (TPN) was associated with 13–31% higher costs for colectomy, pulmonary lobectomy, rectal resection, and pancreatic resection ($P < 0.001$). Critical care consultations were associated with 36–44% higher costs across the six procedures ($P < 0.001$), and inpatient medical consultations were associated with 24–40% higher costs ($P < 0.001$). Daily epidural management was associated with small but significant cost increases for colectomy.

DISCUSSION

In the current era of medical practice, there is growing scrutiny of the *value* each component of care provides to the patient. Value is measured by an outcome of interest to the patient relative to the cost across the continuum of care [15]. This equation is obviously dynamic. There may be expensive processes of care that provide extraordinary outcomes to the patient and are, therefore, deemed valuable. In contrast, any process that does not facilitate improved outcomes is deemed to be of low value, if not waste. Despite CMS categorizing multiple processes of care as "quality metrics," recent research has shown that the associations between many processes and improved patient outcomes are weaker than was previously assumed [14]. The denominator of the value equation for each of these processes, specifically their impact on overall costs of care, has not been defined. The presence of this knowledge gap formed the rationale for this analysis.

TABLE III. Processes of Care by Hospital Characteristics for Medicare Patients From 2005 to 2009

Process of care	Overall (%)	Low volume (%)	High volume (%)	Non-teaching (%)	Teaching (%)	Rural (%)	Urban (%)
Intraoperative							
Pulmonary artery catheter	1.68	1.51	1.74	1.23	2.06	0.52	1.69
Arterial line	34.42	31.80	36.38	26.19	41.56	8.94	34.81
Central venous catheter[a]	23.32	25.99	22.75	23.51	23.17	18.21	23.40
Epidural anesthesia	27.67	27.38	27.90	24.94	30.03	17.32	27.83
Transfusion PRBC or auto transfusion	18.14	22.30	16.76	20.64	15.97	23.34	18.06
Postoperative							
Total parenteral nutrition	5.06	5.20	5.00	5.41	4.75	4.62	5.06
Critical care consultations	14.34	17.63	13.57	14.17	14.48	8.92	14.42
Inpatient consultations	27.45	26.83	27.16	29.86	25.38	12.07	27.69
Daily epidural management	25.28	23.72	26.05	21.88	28.22	14.85	25.44

[a]Central Venous Catheter alone.

These data also highlight the impact of case magnitude on cost analysis. The overall costs associated with more complex procedures, such as pancreaticoduodenectomy and esophagectomy are less impacted by a single process of care. In contrast, the effect size of a single process is more pronounced on less complex procedures, such as colectomy. Likewise, the influence of blood transfusion on overall cost may be ameliorated for larger magnitude procedures, particularly after controlling for other factors, including comorbidities.

PACs are part of a group of processes, including arterial lines and CVCs, which provide data regarding an anesthetized patient's hemodynamic status. There is strong evidence that intraoperative use of PACs provide limited benefit to patients over less invasive monitoring, and may actually induce harm [35,36]. Our analysis determined that elimination of unnecessary PACs, which also require a patient to be postoperatively placed into an intensive care unit environment, could reduce the cost of care by as much as 24%. Unlike PACs, there is little published data associating the use of arterial line and CVC monitoring to patient outcomes. These processes may be indicated for monitoring patients with more comorbidities and/or those requiring larger magnitude resections. For example, beat-to-beat arterial pressure monitoring and blood gas measurement is critically important for many major operations. Our analysis indicated that arterial lines utilization was associated with 2–16% higher costs for an individual [37]. Although some intraoperative processes are necessary components of major cancer surgery, the finding that they frequently increase overall costs indicates that their application be limited to the select group of patients and situations with proven clinical benefit.

While some analyses suggest that epidural analgesia may prolong hospital stays and raise hospital charges [38], our analysis determined that intraoperative epidural analgesia was not associated with increase in overall costs of surgical care, with only minimal cost increases related to the daily management of epidural catheters for colectomy. Although epidural analgesia requires the investment of particular expertise and a collaborative relationship between surgery and anesthesia teams, it frequently provides the benefits of better pain management, higher patient satisfaction and possibly reduces patient mortality [39–42]. The finding that it has only a negligible impact on cost of care favors epidural anesthesia as an effective and valuable process in providing pain management to surgical oncology patients [43].

Regarding postoperative care, the magnitude of the association between these forms of care and costs was large and significant. As many of these services are initiated in an effort to rescue patients from complications [4,5], our results indicate that efforts to prevent and/or to recognize complications early in their evolution represent a prime opportunity to moderate the cost of surgical oncology care. Once complications have occurred the benefits of implementing each process of care should also be examined. For example, the need for TPN was associated with increased costs for colectomy, pulmonary lobectomy, rectal and pancreatic resections. Presumably, TPN use after any of these procedures indicates that the patient had an unexpected complication or delayed recovery [44]. As more emphasis is placed on preoperative nutritional evaluation and modulation, as well as frailty and performance status assessment [45,46], it is hoped that utilization of this costly and questionably beneficial process can be reduced. We certainly do not suggest that rescue measures that save lives and benefit patients should be withheld based on any cost argument; however, in many cases the clinical benefits are dubious or unproven. In these situations, data on cost-association provides a rationale for comparative effectiveness evaluation and more precise application of these treatments to the subset of patients who benefit [16,43,47].

TABLE IV. Processes of Care by Surgical Procedure for Medicare Patients From 2005 to 2009

Process of care	Colectomy (N = 140,146) (%)	Pulmonary lobectomy (N = 48,224) (%)	Rectal resection (N = 24,283) (%)	Pancreatic resection (N = 11,668) (%)	Esophagectomy (N = 3,717) (%)	Pneumonectomy (N = 2,808) (%)
Intraoperative						
Pulmonary artery catheter	1.26	1.81	1.10	4.54	8.72	3.77
Arterial line	15.84	78.88	20.18	74.67	87.60	83.76
Central venous catheter[a]	19.63	24.57	19.94	57.08	52.30	37.11
Epidural anesthesia	15.99	54.92	26.00	40.91	59.05	60.47
Transfusion PRBC or auto transfusion	21.28	8.80	18.07	22.03	10.03	16.88
Postoperative						
Total parenteral nutrition	6.15	0.53	5.88	10.24	3.98	0.89
Critical care consultations	13.15	14.95	10.58	24.23	36.48	25.04
Inpatient consultations	28.81	25.66	22.32	28.99	26.74	29.67
Daily epidural management	14.21	50.34	23.46	40.32	59.21	55.48

[a]Central Venous Catheter alone.

TABLE V. Risk-Adjusted Estimates and *t*-statistics of the Association Between Processes of Care and Hospitalization Costs[b]

Process of care	Colectomy	Pulmonary lobectomy	Rectal resection	Pancreatic resection	Esophagectomy	Pneumonectomy
Intraoperative						
Pulmonary artery catheter	0.237***	0.250***	0.228***	0.279***	0.331***	0.252***
	(16.33)[b]	(13.76)	(6.86)	(10.33)	(7.36)	(3.45)
Arterial line	0.116***	0.00651	0.0863***	0.0447***	−0.0351	−0.0114
	(26.62)	(1.31)	(10.77)	(4.3)	(−1.23)	(−0.44)
Central venous catheter[a]	0.217***	0.161***	0.190***	0.107***	0.192***	0.159***
	(48.78)	(21.05)	(21.67)	(10.1)	(7.53)	(6.2)
Epidural anesthesia	−0.00497	−0.0129*	0.00364	−0.0103	−0.0112	−0.0306
	(−1.02)	(−2.42)	(0.38)	(−0.75)	(−0.45)	(−1.08)
Transfusion PRBC or auto transfusion	0.0787***	0.0832***	0.0675***	−0.0320**	−0.0811**	0.025
	(25.44)	(13.05)	(10)	(−2.97)	(−2.89)	(0.97)
Postoperative						
Total parenteral nutrition	0.214***	0.309***	0.292***	0.131***	0.0501	0.078
	(36.46)	(10.47)	(23.22)	(5.66)	(1.01)	(0.8)
Critical care consultations	0.379***	0.439***	0.387***	0.355***	0.437***	0.429***
	(74.58)	(40.8)	(31.91)	(20.58)	(17.02)	(12.99)
Inpatient consultations	0.251***	0.235***	0.248***	0.238***	0.391***	0.270***
	(74.89)	(38.57)	(33.32)	(17.47)	(14.79)	(9.11)
Daily epidural management	0.0239***	0.0106	0.012	−0.0117	−0.00422	0.00524
	(4.65)	(1.89)	(1.27)	(−0.78)	(−0.16)	(0.18)

[a]Central Venous Catheter alone.
[b]Two-sided *t*-statistics in parentheses; $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

Clearly, some forms of care are difficult to classify into one group [47]. For example, at face-value it is unclear if the use of medical consultation services was routine or only employed when complications developed [48]. In either scenario, these consults were common and significantly associated with increased costs of care across all procedures, even when controlling for patient comorbidity. Therefore, it can be postulated that at least a portion of these consults were medically unnecessary, and their elimination could decrease costs of surgical care.

With any analysis of this type there is concern that referral patterns related to hospital volume influenced resource utilization. In particular, some services which may reflect better quality by high-volume hospitals tend to be performed on sicker patients. Therefore, we performed a sensitivity analysis to risk-adjust our analysis. Following Birkmeyer et al., the use rate of each form of care was calculated for the cancer resection patients by procedure and year at the hospital level [14]. The regressions were performed using these measures instead of the patient-level indicator variables for each service. This sensitivity analysis resulted in slightly more conservative, but similarly significant, coefficients for the forms of care that were associated with higher costs in the base specifications.

Length of stay (LOS) was not included as an explanatory variable, because it could be influenced by several of the processes that are the focus of the analysis. Nevertheless, sensitivity analysis was performed by adding LOS to our cost regressions. Only three coefficients are no longer significant, and one coefficient gains significance when LOS is added. The magnitude of many of the coefficients is decreased, but other than those noted above, they remain significant at the $P<0.001$ level.

A caveat to this study is that the effect of processes of care intended to remediate complications on costs may extend beyond the inpatient episode of care, but the nature of the dataset did not allow for access to post-discharge cost information. Another limitation is that the data were limited to Medicare patients aged 65 or older. But, given that this demographic comprises over half of new cancer cases each year, the cost analysis remains relevant to a majority of cancer patients [6]. One may be concerned that data analysis limited to Medicare patients only may not accurately reflect variation in procedure volume across hospitals and surgeons for these cancer operations. However, a previously published sensitivity analysis of Medicare data comparing hospital procedure volumes across states for these cancer operations determined high correlation with volumes measured using patients of all ages [49].

CONCLUSIONS

Although not definitive, the finding that many of the forms of care frequently added to patients undergoing major cancer surgery are associated with increased overall costs of care has multiple important implications. First, this study demonstrates that process of care implementation is marked by considerable practice variation and is not entirely related to the presence of patient comorbidity. Second, after controlling for comorbidity and hospital volume factors, many of the services that are implemented with the expressed primary purpose of raising the safety of surgical care (and presumed secondary benefit of lowering costs) actually are associated with higher overall costs of care. Third, from a value of medicine perspective the novel finding of a notable process-cost relationship for multiple services mandates a carefully-reviewed and evidenced-based utilization of each process on both the population and individual patient levels. To demonstrate patient-centered value, a conclusive advantage for each practice would have to be demonstrated to compensate for the additional costs of care [15]. Future studies, focusing on "leaner" and more precise perioperative resource utilization that balances safety concerns with comparative and cost-effectiveness are needed to define the patient subsets that truly benefit from each process of care [16,47].

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