Disruption of the solution shop as a hospital organizational structure: Outcomes, Cost, and Cultural Change: A Mayo Clinic Case Study

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Introduction:
A characteristic of hospital surgical care is complexity. While the sources of complexity are multiple, a major driver is that hospital care typically operates as a "solution shop" [1, 2] While the concept originally described a manufacturing model, it is highly applicable to medicine. Solution shops have been described as institutions "structured to diagnose and recommend solutions to unstructured problems."[2] This description is particularly appropriate to hospital-based surgery where care decision making usually relies upon the unique critical thinking, intuition and experience of surgical care provider to devise complex solutions to complex problems.

Solution shop thinking is imbedded in physician culture and education. While it is a critical component of advanced care delivery, systems engineering, process analysis, quality control, manufacturing and management science, and the science of health care delivery all suggest that the uniform application of what amounts to a 19th century craftsman model of medicine is not sufficient to meet 21st century health care needs.

While some hospital care demands solution-shop thinking, its universal application leads to wide practice variation and runs counter to standardized, best practice models; with it the same problem may be approached ten different ways by ten different surgeons. The unwarranted variation that results makes continuous quality improvement very difficult to achieve; it increases cost and reduces quality [3] [4, 5].

The conceptual alternative to the solution shop is the "focus factory" which is characterized by a uniform approach to delivering a limited set of high quality products. Christenson provides multiple examples of this manufacturing concept in health care, from minute clinics, to imagining facilities, to specialty surgical hospitals such as Shouldice [2]. For the general hospital, the critical juncture is to determine which problems are best met with solution shop, or with focus factory approaches to care delivery.

In 2009 Mayo Clinic, Rochester initiated a surgical practice redesign effort with the intention of bringing cost of cardiac surgical care delivery in closer alignment with Medicare reimbursement, while maintaining quality[6]. All clinical divisions in the service line were represented and the effort was supported by finance, practice analysts, information technology, project management and communications. What resulted from that effort was the creation of a "focus factory" within a cardiac surgical service line that currently manages >50% of an annual cardiac surgical population of more than 2000 patients.

Moving from solution shop to focus factory: Cardiac surgical practice redesign began in 2009 with 3 parallel efforts: stakeholder analysis, practice analysis, and an attempt to apply standard management tools (lean, 6-sigma, value stream mapping, etc.) to the surgical care delivery [7]. For practice analysis, we analyzed resource utilization in differing care environments as well as each of the process steps common to all adult patients having cardiac surgery. A primary focus was practice variation.

Several critical observations arose: 1) practice variation was very high, 2) variation was driven by poorly defined or communicated expectations 3) poorly defined or communicated expectations lead to "overcare" 4) care process was organized as a series of "starts and stops", 5) operating room, intensive care unit (ICU) and hospital length of stay (LOS) data indicated that >50% of adult cardiac surgical patients could be expected to have a predictable course of care [8] and 6) the traditional management tools in place were not well suited to the problems at hand.

Operational implementation: Implementation of the focus factory model was built upon six efforts: 1) a mechanism to identify patients suited to focus factory, standardized, care management and confirmation of their continued candidacy based on clinical criteria, 2) the creation of a clinical pathway of linked protocols for the operating room (OR), intensive care unit (ICU) and, progressive care unit (PCU) and standard room and board (floor), 3) building of electronic systems to deliver, support and communicate care protocols, 4.) empowerment of bedside providers to advance care without physician input 5.) a tiered roll out of the patient care model from the operating room to ICU, and then the PCU and 6) co-location of patients by clinical complexity, care process and management needs (an attempt to create a plant within a plant) [9].

Protocols and "Metaorders": Individual protocols for the ICU and PCU were bundled and tiered into "metaorders" (ICU: wean mechanical ventilation, manage fluids, wean hemodynamic infusions, remove indwelling central lines, prepare for ICU discharge, and PCU: remove Foley catheter, remove chest tubes, remove pacemaker wires, advance diet and ambulation). All protocols were designed to make care advancement the default when clinical criteria were met and empowered bedside providers (nurses, physician assistants and respiratory therapists) to manage and advance care without direct physician input. When patients failed to meet clinical criteria required to advance in the care process they fell off protocol, and were managed directly by physicians (solution shop), until clinical status allowed them to return to standardized process management.

Implementation of the focus factory occurred between late 2009 and mid-2011 with system maturity in 2012.

Data analysis: All adult patients who underwent cardiac surgery at Mayo Clinic, Rochester in 2008 and 2012 were retrieved from our Society of Thoracic Surgeons cardiac surgical database. The baseline period for the study was 2008, the year immediately prior to when improvement efforts were initiated. Care process redesign was initiated in July 2009 and became fully mature by June 2011. As such, 2012 was designated as our post-intervention period.

From the adult patients having surgery in 2012, the study group was limited to patients confirmed as suitable to standardized care management at the end of operation(figure 1). Subsequently, the computerized cardiovascular surgery division database was used to select surgical procedures in the following groups to include for subsequent analysis: 1) coronary artery bypass grafting (CABG), 2) valve (replacement or repair) 3) CABG+valve;

and 4) other. (Table 1) ICD-9 codes were used to group patients into each category. Surgical procedures not captured by our primary codes were defined as "other"; these were procedures such as pericardectomy, closure of patent foramen ovale, maze procedure, and aortic root enlargement. Surgical procedures or ICD-9 codes that were not represented in both 2008 and 2012 (robotic valves, percutaneous valves, etc.) were excluded from the analysis. Also excluded were adult congenital, ventricular assist device, transplant patients, and emergency cases. Electronic confirmation of focus factory participation combined with procedural selection criteria, using ICD-9 codes and propensity score matching limited the analysis to 769 patients for each of 2008 and 2012. (Figure 1)

Propensity Score Matching: To ensure that the patients in the pre- and post-intervention periods were similar, we constructed a sample of matched patients using propensity score matching (PSM).[10] More specifically, a propensity score or probability was estimated using a logistic regression that modeled the probability of whether a patient belonged to 2008 vs. 2012 cohort based on the following characteristics: age, gender, operative categories, and baseline diagnosis of the following comorbid conditions: diabetes, hypertension, chronic heart failure, chronic obstructive pulmonary disease (COPD), myocardial infarction, coronary artery disease, and valvular disease. Then, patients from the pre- and post-intervention cohorts were matched based on nearest neighbor one-to-one matching without replacement,[11] yielding 769 patients in each of the two study cohorts. Prior to matching, differences existed between 2008 and 2012 patient cohorts in prevalence of diabetes, COPD, and some operative categories. In addition, 2012 patients were an average of a year older, and a higher proportion had hypertension (68% in 2012 vs. 64% in 2008). However, these differences in patient characteristics were eliminated following propensity score matching. (Table 1).

The **targeted outcomes** measures were clinical process and outcomes measures, resource utilization and cost measures. Clinical outcomes to assure safety of the standardized care model included respiratory failure and return to mechanical ventilation, ICU or hospital readmission, as well as 30 day morbidity and mortality measures obtained from our Society of Thoracic Surgeons outcomes database. Utilization measures included length of stay (from the date of index surgery to discharge, which includes ICU, intermediate care, and standard room and board stay), hours in ICU, hours in PCU, and minutes in the operating room.

Standardized costs were calculated and analyzed for only the OR, ICU, PCU, and the hospital total length of stay (ICU, PCU, and general room and board combined) based on billed charges. Operating room billed charges consist of a base amount plus an additional amount tied to 15-minute increments. Length of stay charges are billed in full day increments where a new day begins at midnight. The 2012 charge for each unit of service was multiplied by the appropriate 2012 Medicare cost report line level cost-to-charge ratio for both the 2008 and 2012 patients to create standardized costs. This method of standardization is commonly used in research.[1,2] Standardized costs associated with professional services, or other hospital services such as pharmacy, supplies, laboratory, pathology, diagnostic radiology, imaging, cardiology, and physical therapy are not included.

Pertinent patient and procedural characteristics were described and compared between these two groups (baseline vs. post intervention) using Rank-sum test for continuous variables and the Fisher's exact test for categorical variables. Data analysis then consisted of mean and standard deviation or median with interquartile range determination for continuous variables and percent quantification for categorical variables. Two-tailed p-value of < 0.05 was considered statistically significant.

Results: During the 12 month post-intervention interval 2026 adult patients were identified in the cardiac surgical database, of those, 1349 adult patients (67%) were confirmed as suitable for standardized care management at the end of surgery. From those populations propensity matching was done resulting in 769 matched patients in each year(Figure 1). Table 1 shows patient and surgical characteristics of the propensity matched 2008 and the post-intervention, 2012 groups. Propensity matching was robust with no differences in patient or surgical characteristics between the pre and post intervention groups.

Resource Utilization: The implementation of a focus factory care delivery approach reduced resource utilization in all care environments. In the operating room mean time per case was reduced from 322±99 in 2008 to 303±83 minutes in 2012 ($P<0.001$). Total hours in ICU was reduced from a 2008 mean of 37.6±31.5 hours to a mean of 27.8±17.9 hours ($P<0.001$). (Table 2)

More notable was decreased variation of ICU length of stay (LOS). This is reflected in the interquartile (IQ) range and the narrowing of the difference between median and mean ICU LOS in 2012. In 2008 the median time and IQ ranges were 26.5 hours (23.7, 45.4) and in 2012 were 22.7 hours (20.1, 26.2). The decrease in variation in ICU LOS for matched patients is demonstrated in Figure 2.

Time in the progressive care unit was also reduced in 2012 relative to 2008, from a mean of 113±49 to 101±37 hours ($P<0.001$) (Table 2). Together these changes reduced hospital length of stay from start of surgery from a mean of 6.3±3 days to 5.5±1.7 days ($P<0.001$). (Table 2) As for the ICU, variation in hospital length of stay was markedly reduced (figure

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[1] According to the University Health System Consortium's Clinical Data Base/Resource User Manual, UHC calculates a cost per discharge based on the charges of each discharge, the cost-to-charge ratios from each hospital's Medicare Cost Report, and area wage indices.

[2] The Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP) database includes cost-to-charge ratios for the NIS, KID, and SID databases so that the charges may be converted to costs.

3). Median and interquartile range for hospital LOS was reduced from 6 days (IQ range: 5.0, 7.2) in 2008 to 5.2 days (IQ range: 4.3, 6.3) days in 2012 ($P<0.001$).

Clinical Outcomes: Implementation of a focus factory approach to cardiac surgical care in was not associated with in-hospital complications such as respiratory failure following weaning from mechanical ventilation (1% vs. 0% in 2008 and 2012 respectively, $P=0.22$) or readmission to the ICU after discharge (2% vs. 2%, 2008 and 2012 respectively $P=1.0$). For 30-day outcomes there was no increase in mortality or in hospital readmission. (Table 3) Patients managed with a focus factory approach in 2012 did not have an increase in morbidity relative to 2008. Overall, the focus factory model was associated with better 30-day outcomes; sepsis, pneumonia and renal failure were all significantly reduced at 30 days in the 2012, focus factory population. (Table 3)

Cost Outcomes: Standardized cost for each care environment and for the hospital length of stay were all significantly reduced. The mean standardized cost for the operating room ($10321 vs. $9848, $P<0.001$), the ICU ($4313 vs. $3514, $P<0.001$), the PCU ($8443 vs. $7468, $P<0.001$) and for the hospital length of stay ($12795 vs. $10978, $P<0.001$) were all significantly reduced following the intervention. Overall, , the mean per patient cost of care for this population was reduced by 15% relative to 2008 while the median cost was reduced by 14% . (Figure 4) As for resource utilization, implementation of a focus factory approach in 2012 was associated with a decrease in cost variation in each care environment.

Discussion

Our results demonstrate the efficacy of a standardized care model to reduce cost and improve the quality of care. The process represents a disruption of the hospital as only a solution shop [12]. Rather than treating all patients as highly complex and requiring unique problem solving, we identified a large segment of patients whose care is amenable to a focus factory approach.

Our success resided in creation of standardized clinical pathway that incorporated integrated and tiered protocols designed to make care advancement the default, identification of candidates, clear communication of candidates and care expectations, empowerment of bedside providers to advance care, and electronic mechanisms to support the care process. Operationally this represents disruptive innovation,[2, 12] in that lower-level providers were given knowledge (protocols) and technology (electronic tools) that enabled them to function to the maximum of their training and disrupt the care model of higher level providers (surgeons and physicians).

Clinicians may hesitate to implement protocols and even “best practices” if decisions are not made by physicians at the point of care. We show that a comprehensive standardized care model did not increase morbidity or mortality either in the hospital or in 30-day outcomes. In fact, we found that, our focus factory approach was associated with decreased pneumonia, sepsis and renal failure at 30 days. It is notable that these three outcomes may be adversely affected by in-hospital care processes, such as duration of mechanical ventilation, duration of indwelling catheters, diabetes, fluid, and vasoactive drug management [13, 14]. In our care process model each was managed by protocol.

In addition to improved process[15], better quality and care outcomes, the application of the focus factory model reduced resource utilization in the operating room, intensive care unit and on the floor for those patients. Using standardized cost models this translated into a projected reduction in mean cost of care of 15% in 2012.

Recognizing that the observational design of our study was a limitation, we minimized the potential for confounding bias through propensity score matching. In spite of the propensity matching there remains the possibility of residual confounding due to unmeasured factors that propensity matching cannot account for. However the demographic, surgical and medical comorbidities we captured in our propensity analysis compromise all major risk factors for adverse outcomes in cardiac surgery so we anticipate that any unaccounted factors could have no more than minimal effects on our results.

We recognize that a focused factory approach, like a solution shop approach is not suitable to all patients. Therefore, an integrated health system like Mayo Clinic that accommodate both "focused factory" and "solution shop" models within it may better serve the needs of patients who prefer one-stop-shop model of care. However, running a solution shop to care for a range of specific and complex patients (the equivalent of specialty product lines) may become increasingly difficult in the light of Medicare's value based purchasing (VBP) program by which Medicare is trying to link reimbursement to quality but not quantity of care provided. While Medicare's efforts at linking payments to quality is laudable, one of the unintended consequences may be that providers may become more risk-averse, as they may stop providing care to the complex surgical patients who are more likely to have adverse outcomes and in turn result in a lower VBP score, and hence the potential for losing up to 1.25% of Medicare's base DRG amounts[17] [18].

Surgical care, particularly cardiac surgical care, can be highly complex and is prone to significant variation in care process. The historical solution shop model contributes to unwarranted variation, lower quality and higher cost when applied to universally. We demonstrate that creating a focused factory model within a larger service line, a factory within a factory, is highly effective in achieving higher quality and lower cost. This model can exist alongside the traditional solution shop model and preserve its critical value for complex care, although the latter comes to exist with a significantly reduced practice footprint.

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Table 1: **Comparison of Group Characteristics between 2008 and 2012 after Propensity Matching**

		Year of Surgery		
Characteristic/feature	**All (n=1538)**	**2008 (n=769)**	**2012 (n=769)**	**P-value**
Age mean (SD)	65.5 (13.8)	65.2 (13.9)	65.7 (13.7)	0.38
Male gender (%)	67.0	68.7	65.4	0.18
Diabetes (%)	22.0	20.5	23.5	0.16
Hypertension (%)	69.1	68.8	69.3	0.83
Diagnosis of CHF (%)	12.8	12.6	13.0	0.82
Chronic Lung Disease (%) stage II-IV	6.9	7.3	6.5	0.55
Previous myocardial infarction (%)	11.6	12.9	10.3	0.11
Coronary artery disease (%)	47.5	48.2	46.7	0.54
Valvular heart disease (%)	83.2	82.6	83.9	0.49
Operative category (%)				0.35
Coronary artery bypass grafting (CABG)*	23.1	22.8	23.5	
Valve (Repair or Replacement)*	61.6	61.4	61.8	
CABG + Valve*	15.1	15.9	14.3	
Other*	0.2	0.0	0.4	

*Primary operation may be with or without an associated procedure, e.g. arrhythmia surgery, patent foramen ovale closure, pericardiectomy, etc.

**Primary operation is those other than CABG or valve surgery, e.g., septal myectomy, aortic aneurysm, isolated arrhythmia surgery, patent foramen ovale closure, pericardiectomy, etc.

P-value by rank sum for continuous variables, Chi-square for categorical variables except operative category, Fisher's exact test for operative category.

Table 2: **Comparison of Utilization between 2008 and 2012 after Propensity Matching**
P-values by Rank sum test,

		Surgery Year - Post Matching		
Characteristic/feature	**All (n=1538)**	**2008 (n=769)**	**2012 (n=769)**	**P-value**
Hospital Length of Stay (surgery to discharge)				<0.001
Mean (SD)	5.9 (2.5)	6.3 (3.0)	5.4 (1.7)	
Median (IQR)	5.2 (4.2,6.9)	5.9 (4.9,7.1)	5.0 (4.0,6.1)	
Range	2.7 to 46.8	3.0 to 46.8	2.7 to 14.1	
Hours in ICU				<0.001
Mean (SD)	32.7 (26.1)	37.6 (31.5)	27.8 (17.9)	
Median (IQR)	24.7 (21.6,29.8)	26.5 (23.7,45.4)	22.7 (20.1,26.2)	
Range	7.5 to 460.2	9.1 to 460.2	7.5 to 165.4	
Hours in PCU				<0.001
Mean (SD)	107.3 (44.1)	113.2 (49.1)	101.4 (37.5)	
Median (IQR)	97.1 (74.9,122.2)	98.63 (78.0,124.9)	95.93 (73.9,120.5)	
Range	0.00 to 480.2	0.00 to 480.2	0.5 to 291.8	
Minutes in OR				<0.001
Mean (SD)	313.0 (91.8)	322.4 (98.9)	303.5 (83.1)	
Median (IQR)	302.5 (241.0,366.0)	310.0 (250.0,374.0)	295.0 (235.0,358.0)	
Range	157.0 to 801.0	157.0 to 801.0	165.0 to 705.0	

Table 3: **Complications and Mortality**

Characteristic/feature	All (n=1538)	Surgery Year – Post Matching 2008 (n=769)	2012 (n=769)	P-value
Reoperation/bleeding (30 days), %	2.0	2.6	1.3	0.065
Sternum-Superficial or Deep (30 days), %	0.6	0.9	0.3	0.18
Sepsis (30 days), %	0.5	0.9	0.0	0.015
Neurologic (30 days), %	1.0	1.3	0.7	0.19
Stroke-Permanent (30 days), %	0.4	0.5	0.3	0.69
Pneumonia (30 days), %	0.8	1.3	0.3	0.02
ARDS (30 days), %	0.1	0.1	0.1	1.00
Not available, (no.)	3		3	
Renal Failure (30 days), %	0.8	1.4	0.3	0.012
Mortality – 30 day %	0.6	0.8	0.3	0.30
Not available, (no.)	141	10	131	
Readmission ≤30 days from procedure, %	7.5	8.3	6.8	0.24
Not available, (no.)	1	1		

P-value by Chi-square for complications (reoperation/bleeding, neurologic, pneumonia, renal failure, readmission), Fisher's exact (sternum-superficial or deep, sepsis, stroke-permanent, ARDS, and 30-day Mortality)

Figure Legends

Figure 1. Study design for outcomes, utilization and standardized cost analysis in propensity matched population 2012 and 2008 adult cardiac surgical populations.

Figure 2. Vertical histograms showing distribution for duration of ICU length of stay control (2008-upper panel) and intervention (2012- lower panel) groups (n = 769 for each group). Median and mean values as well as 95% confidence intervals are shown below respective panels.

Figure 3. Vertical histograms showing distribution for duration of hospital length of stay control (2008-upper panel) and intervention (2012- lower panel) groups (n = 769 for each group). Median and mean values as well as 95% confidence intervals are shown below respective panels.

Figure 4. Distribution of costs pre- and post-implementation of focus factory model is shown. The red line of in each box indicates the median cost; the lower and upper border of the boxes show the 25th and 75th percentiles of the cost distribution, while the stars (*) indicates the outliers. (n=769 per group).

Figure 1

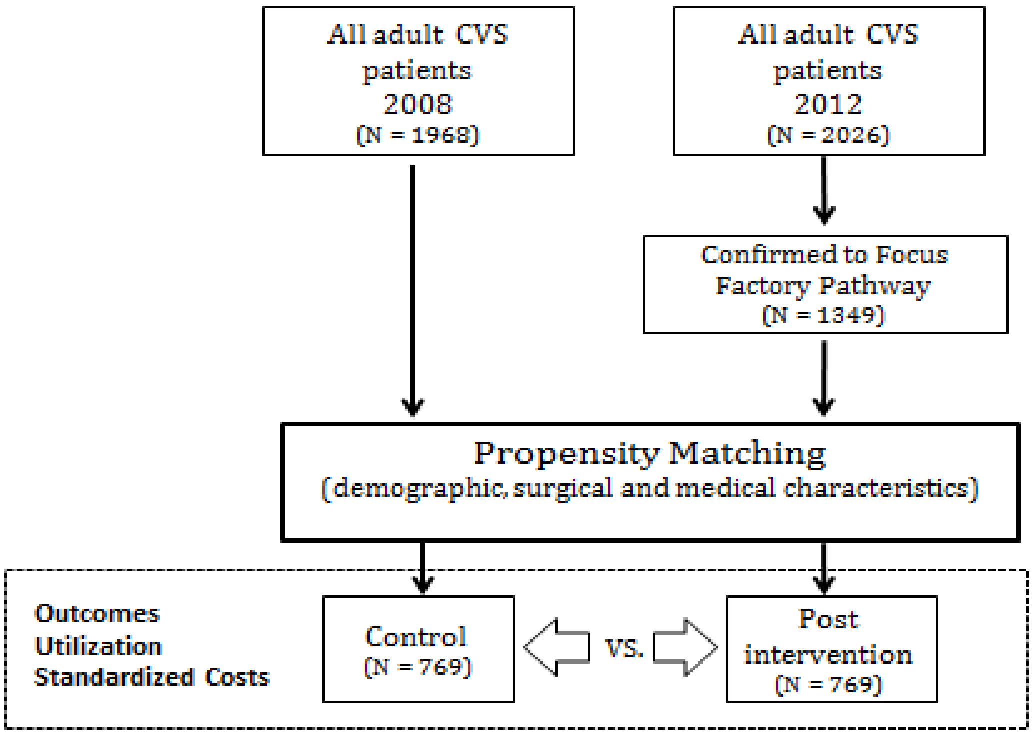
All adult CVS patients 2008 (N = 1968)
All adult CVS patients 2012 (N = 2026)
Confirmed to Focus Factory Pathway (N = 1349)
Propensity Matching
(demographic, surgical and medical characteristics)
Outcomes
Utilization
Standardized Costs
Control (N = 769)
VS.
Post intervention (N = 769)

Figure 2

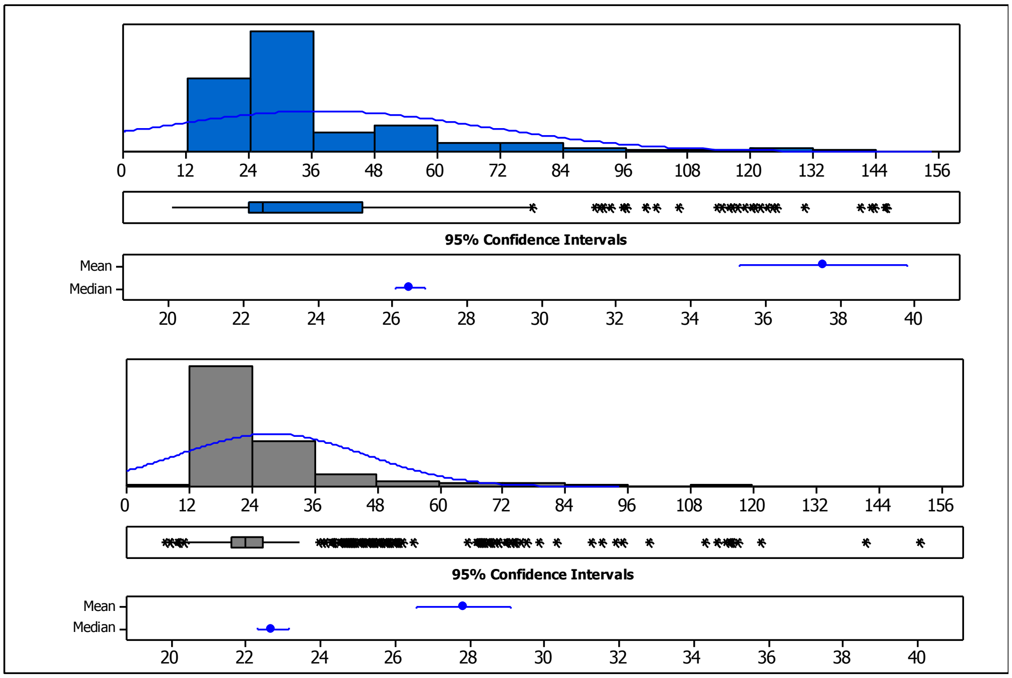
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Figure 3

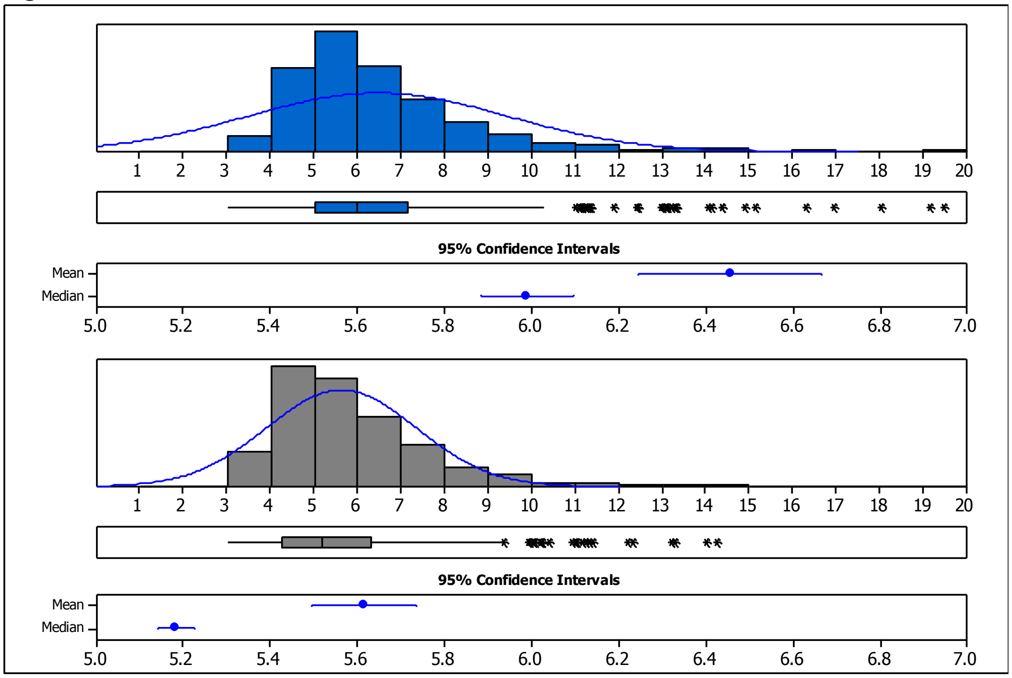
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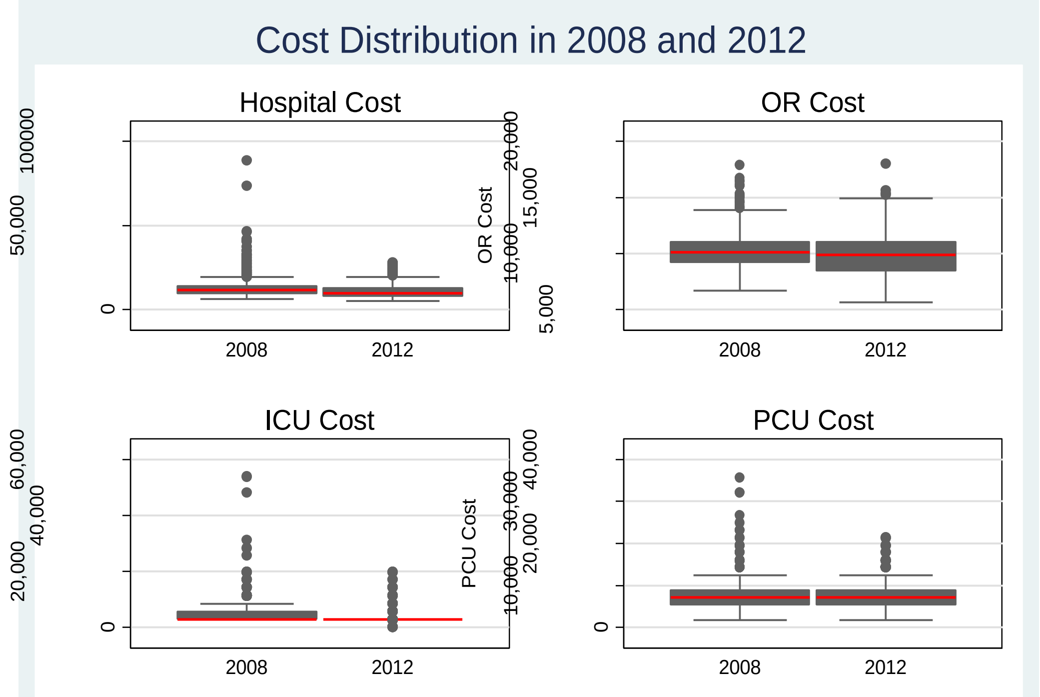
Figure 4



All costs were reported in 2012 U.S. Dollars.

ICU=Intensive Care Unit; PCU=Progressive Care Unit; OR=Operating Room.