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# Tackling the economic burden of postsurgical complications: would perioperative goal-directed fluid therapy help?

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## Abstract

### Introduction

Pay-for-performance programs and economic constraints call for solutions to improve the quality of health care without increasing costs. Many studies have shown decreased morbidity in major surgery when perioperative goal directed fluid therapy (GDFT) is used. We assessed the clinical and economic burden of postsurgical complications in the University HealthSystem Consortium (UHC) in order to predict potential savings with GDFT.

### Methods

Data from adults who had 10 major surgical procedures in 2011 were screened in the UHC database. Thirteen post-surgical complications were tabulated. In-hospital mortality, hospital length of stay and costs from patients with and without complications were compared. The risk ratios reported by the most recent meta-analysis were used to estimate the potential reduction in post-surgical morbidity with GDFT. Potential cost-savings were calculated from the actual and anticipated morbidity rates.

### Results

A total of 75,140 patients met the search criteria, and 8,421 patients developed one or more post-surgical complications (morbidity rate 11.2%). In patients with and without complications, in-hospital mortality was 12.4% and 1.4% ( $P < 0.001$ ), mean hospital length of stay was  $20.5 \pm 20.1$  days and  $8.1 \pm 7.1$  days ( $P < 0.001$ ) and mean direct costs were \$47,284

$\pm 49,170$  and  $\$17,408 \pm 15,612$  ( $P < 0.001$ ), respectively. With GDFT, morbidity rate was projected to decrease to 8.0 to 9.3%, yielding gross costs savings of \$43 m to \$73 m for the study population or \$569 to \$970 per patient.

## Conclusion

Postsurgical complications have a dramatic impact (+172%) on costs. Potential costs savings resulting from GDFT are substantial. Perioperative GDFT may be recommended not only to improve quality of care but also to decrease costs.

## Introduction

Pay-for-performance programs and economic constraints call for solutions improving the quality of health care without increasing costs [1]. In this respect, the American Society of Anesthesiology is developing a Perioperative Surgical Home program in order to optimize quality and continuity of care for surgical patients [2,3]. Perioperative Goal Directed Fluid Therapy (GDFT) is a general term referring to targeted hemodynamic and fluid management using parameters such as stroke volume, cardiac output, and/or oxygen delivery, in conjunction with standard vital signs in managing patients during and immediately after surgery. Many studies have shown decreased morbidity in major surgery when GDFT is used [4,5] and it is now recommended by the National Health Service in the UK [6], by the French Society of Anesthesiology [7], and by the Enhanced Recovery After Surgery (ERAS) society in Europe [8]. Despite this, adoption of GDFT in the United States is poor [9,10]. Perioperative GDFT may require the use of hemodynamic monitoring equipment, such as minimally invasive cardiac output monitoring, beyond that used for simple, routine surgeries. The cost of monitoring equipment for GDFT may be a barrier to adoption.

By reducing complication rates, GDFT would be expected to decrease cost [11]. Indeed, a favorable financial impact of GDFT resulting from reduction of complication rates has been reported [12,13]. These studies, however, are not current, and involved the use of the pulmonary artery catheter for monitoring. With the exception of cardiac surgery and liver transplantation, the pulmonary artery catheter is no longer commonly used for perioperative hemodynamic optimization, having been replaced by less invasive technologies. To date there have been no reports of large, randomized, controlled trials assessing the financial impact of GDFT.

The University HealthSystem Consortium (UHC) is an alliance of 120 academic medical centers and 300 of their affiliated hospitals [14]. Query of their database allows the determination of complications and costs of care in surgical patients. These data, in conjunction with the outcome impact of GDFT that has been reported in the medical literature, allows an estimation of potential GDFT-related cost-savings in major surgeries in the UHC.

The goal of our study was twofold: Describe the clinical and economic burden of postsurgical complications in the UHC, and predict the economic impact of GDFT implementation.

# Materials and methods

De-identified data from all adults who had major non-cardiac surgery in 2011 were screened in the UHC database. Permission to perform and report the results of this study was provided by the University of California San Diego Human Research Protections Program. This committee waived the need for informed consent, since this was a database study.

## Patient selection

Ten major surgical procedures were selected based on previous studies showing GDFT-associated positive outcomes [15-29]. Corresponding ICD9 codes were used to search specific procedures in the UHC database (Table 1). Because GDFT has thus far been shown to be effective only in adults, a restriction was used ensuring that only adult ( $\geq 18$  years old) patients were queried.

**Table 1 The 10 major surgical procedures queried in the University HospitalSystem Consortium Database, the corresponding ICD9 codes and studies showing a morbidity reduction with Perioperative Goal Directed Therapy (PGDT)**

Surgical procedure	ICD9 codes	Author (reference)
Abdominal aortic aneurysm open repair	38.44	Benes [15], Kuper [19], Lobo [20], Pearse [22], Wilson [29]
Aorto-iliac & peripheral bypass	39.25, 39.29	Bisgaard [16], Kuper [19], Pearse [22], Wilson [29]
Esophagectomy	42.40, 42.41, 42.42	Boyd [17], Kuper [19], Lobo [20], Pearse [22], Wilson [29]
Gastrectomy	43.5, 43.6, 43.7, 43.81, 43.89, 43.91, 43.99	Boyd [17], Kuper [19], Lobo [20], Pearse [22], Wilson [29]
Colectomy	45.71-45.76, 45.79, 45.81-45.83	Benes [15], Gan [18], Kuper [19], Noblett [21], Pearse [22], Ramsingh [24], Wakeling [28]
Resection of rectum	48.40, 48.43, 48.49-48.52, 48.59, 48.61-48.65, 48.69	Benes [15], Gan [18], Kuper [19], Noblett [21], Pearse [22], Ramsingh [24], Wakeling [28], Wilson [29]
Hepatectomy	50.22, 50.3	Pearse [22], Ueno [26],
Pancreatectomy	52.51-52.53, 52.59, 52.6, 52.7	Benes [15], Lobo [20], Ramsingh [24]
Total cystectomy	57.71, 57.79	Boyd [17], Gan [18], Kuper [19], Pearse [22], Pillai [23], Ramsingh [24], Wilson [29]
Femur & hip fracture repair	79.15, 79.25, 79.35, 79.85, 79.95	Kuper [19], Sinclair [25], Venn [27]

## Clinical data collection

In-hospital post-operative complications queried, as defined by the UHC, included postoperative stroke, gastrointestinal hemorrhage, catheter associated urinary tract infection, reopening of surgical site, acute myocardial infarction, coma or stupor, nosocomial pneumonia, wound infection, sepsis, pulmonary embolism or deep venous thrombosis, respiratory failure, hematoma & wound dehiscence. Morbidity rate was defined as the proportion of patients developing at least one complication during their hospital stay. Patients were sorted into two groups: those with complications and those without. For each group, in-hospital mortality and hospital length of stay (mean  $\pm$  SD) were extracted from the UHC database and compared.

## Cost data collection and cost-savings projection

Direct costs (mean  $\pm$  SD) related to the in-hospital treatment of patients with and without complications were obtained from the UHC database and compared. Direct costs are those associated with the actual procedures, they do not include overhead and wages for healthcare

personnel. The most recent GDFT meta-analysis was used to estimate the potential reduction of postoperative morbidity from GDFT [5]. This meta-analysis reported an average odd ratio of 0.77 with a confidence interval ranging from 0.71 to 0.83. Potential cost-savings were determined by using the projected number of patients developing one or more complication and the estimated related costs. This analysis was performed for the entire cohort, as well as for each surgical procedure. The analysis assumes complete, new implementation of GDFT.

## Statistical analysis

In-hospital mortality, hospital length of stay and costs were compared between patients with and without complications. Mortality rates (%) were compared with a Chi-square test, hospital length of stay (mean  $\pm$  SD) and costs (mean  $\pm$  SD) were compared with a two-sample *t*-test with unequal variance.

## Results

A total of 75,140 patients from 222 medical centers met the search criteria. Numbers of patients per surgery group are reported in Table 2. 8,421 patients developed one or more of the 13 post-surgical complications extracted from the database (morbidity rate 11.2%). **Most common post-surgical complication** was **wound infection** (4.0%), followed by **sepsis** (1.8%), nosocomial **pneumonia** (1.7%), reopening of **surgical site** (1.6%), pulmonary **embolism** or deep venous thrombosis (1.5%), and **respiratory failure** (1.4%). All other complication rates were less than 1% (Figure 1). Morbidity rates for each surgery group are presented in Table 2.

**Table 2 Clinical and economic characteristics of the study population**

Surgery	Patients, n	Morbidity, %	Mortality, %		HLOS, days		Direct Cost, \$	
			with	without	with	without	with	without
AAA open repair	2 040	19.6	20.8	6.0	23.9 $\pm$ 17.2	10.3 $\pm$ 8.2	76169 $\pm$ 55530	30451 $\pm$ 24023
Vascular bypass	6 765	9.5	10.3	1.1	17.5 $\pm$ 15.2	7.3 $\pm$ 6.5	42202 $\pm$ 39618	16790 $\pm$ 12601
Esophagectomy	1 794	12.5	6.3	2.4	23.2 $\pm$ 15.5	13.1 $\pm$ 11.7	59382 $\pm$ 48850	32457 $\pm$ 30571
Gastrectomy	5 995	8.7	11.7	1.0	25.0 $\pm$ 21.9	6.8 $\pm$ 7.7	54879 $\pm$ 45868	16159 $\pm$ 15986
<b>Colectomy</b>	19 055	<b>16.0</b>	<b>15.2</b>	2.6	<b>23.1 <math>\pm</math> 25.2</b>	9.6 $\pm$ 8.2	49160 $\pm$ 56975	17158 $\pm$ 16481
Resection of rectum	4 251	9.2	4.9	0.4	16.2 $\pm$ 13.0	7.1 $\pm$ 5.3	29874 $\pm$ 27882	13723 $\pm$ 10020
Hepatectomy	4 934	7.6	14.8	0.7	17.9 $\pm$ 16.6	6.3 $\pm$ 4.4	48961 $\pm$ 50382	16501 $\pm$ 12080
Pancreatectomy	6 564	14.6	11.4	0.4	21.7 $\pm$ 19.1	9.7 $\pm$ 6.9	53217 $\pm$ 50882	20888 $\pm$ 15390
Cystectomy	4 036	10.9	5.2	0.4	19.3 $\pm$ 13.0	9.1 $\pm$ 5.4	43598 $\pm$ 34224	20669 $\pm$ 10511
F&H fracture repair	19 706	7.3	10.6	0.9	14.6 $\pm$ 12.2	6.6 $\pm$ 5.9	33890 $\pm$ 33115	14919 $\pm$ 13575

AAA = abdominal aortic aneurysm, F&H = femur & hip.

In-hospital mortality, hospital length of stay (HLOS) and direct costs were compared between patient with one or more complications (with) and patients without any complication (without). All comparisons were statistically significant with a *p* <0.001.

**Figure 1 Type (x axis) and number (y axis) of post-operative complications queried in the study population (75,140 patients).** P = pneumonia; SS = surgical site; PE = pulmonary embolism; DVT = deep venous thrombosis; MI = myocardial infarction; GI = gastro-intestinal; UTI = catheter associated urinary tract infection.

## Clinical impact of postsurgical complications

In patients with one or more complications and in patients without any complication in-hospital mortality was **12.4% and 1.4%** (difference 11.0%, *p* <0.001), and mean hospital length of stay was **20.5  $\pm$  20.1 and 8.1  $\pm$  7.1** days (difference 12.4 days, *p* <0.001),

respectively (Table 2). The impact of postsurgical complications on in-hospital mortality and hospital length of stay for each surgery group is presented in Table 2.

### **Economic impact of postsurgical complications**

Average direct cost was \$47,284 ± 49,170 and \$17,408 ± 15,612 (difference \$29,876,  $p < 0.001$ ) per patient with one or more complications and per patient with no complications, respectively (Table 2). Thus, in 2011 the UHC spent a total of \$252 M ( $\$29,876 \times 8,421$  patients) to treat postsurgical complications in the study population. The economic impact of postsurgical complication for each surgery group is presented in Table 2.

### **Projected cost-savings with implementation of GDFT**

Projected number of patients developing one or more complication, assuming an odd ratio ranging between 0.71 and 0.83, was 5,979-6,989 (morbidity rate 8.0-9.3%, Figure 2). Thus, after implementation of GDFT, projected gross savings would be \$569-\$970 per patient and \$43-73 M for the entire UHC study population (Figure 2). Projected cost savings for each surgery group are presented in Figures 3 and 4.

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**Figure 2 Actual and projected morbidity rates, complication costs and total hospital costs with GDFT implementation.**

**Figure 3 Projected cost savings per patient with perioperative Goal Directed Fluid Therapy.** Each vertical black bar represents the range between minimum and maximum savings. AAA = abdominal aortic aneurysm.

**Figure 4 Projected total cost savings for the University HospitalSystem Consortium study population with perioperative Goal Directed Fluid Therapy.** Each vertical black bar represents the range between minimum and maximum savings.

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## **Discussion**

In our large UHC patient population, the occurrence of one or more postsurgical complications had a dramatic impact on in-hospital mortality (multiplied by 9) and hospital length of stay (multiplied by 2.5). Although impressive, these findings are consistent with the results of a recent study [30] done in 34,256 surgical patients discharged from a nonprofit 12-hospital system in the southern United States. In that study, in-hospital mortality was 21 fold greater (12.3 vs 0.6%) and hospital length of stay was 4.7 fold greater in patients who developed one or more postsurgical complications.

Postsurgical complications also had a very significant impact on costs (+172%), the extra-costs for treating patients developing one or more complications exceeding by far the cost of the surgical procedure itself (\$29,876 vs \$17,408). Our cost findings are consistent with previous and smaller studies. In 1,200 patients undergoing major abdominal surgery, Vonlanthen et al. [31] showed that patients with an uneventful course had mean costs per case of \$27,946, whereas patients with one or more complications had a mean cost per case \$34,446 higher. In 2,250 patients undergoing general and vascular surgery, Boltz et al. [32] showed that for patients developing 1, 2, 3 or more complications the excess costs were \$6,358, \$12,802 and \$42,790, respectively. In the above mentioned 34,256 patients cohort



study [30], including major and minor procedures (e.g. appendectomy), the average cost difference between a patient with and without complications was \$22,398. These findings demonstrate the dramatic impact of complications on hospital costs and highlight a relevant savings capacity for major surgical procedures.

In our study, potential cost savings related to the use of GDFT were substantial, with projected gross savings of \$569-\$970 per patient treated. This analysis revealed that potential savings per patient depend on the surgical procedure, ranging from \$235-\$402 for femur and hip fracture to \$1,523-\$2,599 for abdominal aortic aneurysm open surgery (Figure 2). Given the volume of procedures, total savings for UHC were the most significant (\$16.6 M-28.3 M) for colectomies (Figure 3). **Our cost-saving estimations are lower than those reported by a previous UK prospective trial** [13] showing a cost reduction of £1259 (\$1889) per patient, and much lower than another trial [12] reporting £3467 (\$5201) cost-savings per patient when GDFT was used. As far as we know, these are the only two prospective studies thus far comparing the cost for treating surgical patients with and without GDFT. These single centre evaluations have been done in a limited number of patients monitored with a PAC 14 and 20 years ago in UK hospitals. Anesthesia and surgical practices, as well as health care costs, have dramatically changed over the last decades, rendering their applicability to current practices in the US questionable. We provide in this article a cost-saving estimation based on the most recent GDFT meta-analysis and a very large number of patients. This is the first clinical and economic prediction of its kind based on real US data. Our estimations are also lower than a recent cost simulation done in Sweden and suggesting that €1882/patient (\$2258) could be saved if GDFT was to become the new standard of care in elderly hip fracture patients [33].

Although free solutions have been proposed for GDFT [34], cardiac output monitoring techniques such as transesophageal Doppler and arterial pulse contour methods are often used [35]. The cost of these technologies varies a lot from one region to the other (depending on reimbursement policies) and from one hospital to the other (depending on the volume of products used or bought every year by hospitals or group purchasers, respectively). If one assumes the cost of GDFT technologies, including capital investment for hemodynamic monitors and disposable sensors, to be approximately \$300/patient in the US, the net savings are projected to be \$269-\$670 per treated patient. When considering the implementation of GDFT, potential additional costs related to staff training and change in fluid or/and drug usage may also be considered. Training and technical support are usually provided (at least in part) by cardiac output monitoring companies, the use of vasoactive and inotropic drugs is not part of most recent GDFT guidelines [6-8], and recent clinical studies have shown that the net effect of GDFT strategies is usually no change [5] if not a decrease [36] in the total amount of fluid administered to patients during the perioperative period. However, GDFT costs may significantly vary from one medical center to the other, depending on the hemodynamic parameter used for GDFT (pulse pressure variation vs stroke volume), the cardiac output monitor amortization (large volume vs low volume of surgeries), and the fluid used (albumin vs crystalloid). Therefore, another way to look at our data is to consider the potential savings of \$569-\$970/patient as the upper limit for all GDFT related costs. Then, a fair evaluation of the potential savings can be made on a case by case basis.

Our analysis probably underestimates the potential scope of financial benefit of GDFT for several reasons. First, the analysis was strictly limited to major surgeries in which outcome has already conclusively been shown to be improved by the use of GDFT. There are other surgeries, such as major orthopedic spine, solid organ transplantation, major gynecologic, in

which this approach would likely be associated with fewer complications [6,19]. Second, the UHC database, being an administrative database, has the advantage of containing reliable financial information, but also the disadvantage of underestimating the real incidence of post-surgical complications. In a comparison study, Steinberg et al. [37] reported a 28% morbidity rate with the National Surgical Quality Improvement Program (NSQIP) database (a clinical database specifically designed to collect up to 21 complications) and a 11% morbidity rate with the UHC database in the same surgical population. In the same study [37], the incidence of wound infection was 13% and only 1% with the NSQIP and the UHC database, respectively. Third, we used the odd ratio reported by the most recent GDFT meta-analysis [5] to estimate the potential reduction of postoperative morbidity. Because quality of care has improved over time, results of meta-analysis may be questioned because they include studies done a long time ago. A meta-analysis published in 2011 [4] looked specifically at the effects of GDFT over time. Interestingly, the morbidity reduction with GDFT was observed similarly for studies published in the 1980's, the 1990's and after 2000. The odd ratio for studies published after 2000 was 0.38 (0.29-0.50). If we had used this odd ratio, the projected savings would have been almost 2 times greater than those we report in the present study. Finally, our estimation does not take into account costs related to hospital readmissions. Post-surgical complications are the main cause for hospital readmission and it has been recently suggested that reducing complications may be the most efficient way to decrease readmissions and related costs [38].

Our analysis was limited to academic centers. The savings per patient may be different when the private sector is considered, and the total potential savings to the U.S. healthcare system would be considerably more if the private sector were to be included. The potential clinical benefits and hence cost savings were derived from a meta-analysis, which could have incorporated “reporting bias”, with positive studies having been more likely published. We considered the same post surgical morbidity reduction with GDFT for all surgical procedures. Although previous meta-analysis [4,5] did not find any interaction between the type of surgery and the effect of GDFT, this may not always be true. Also patients with comorbidities may benefit more from GDFT, but this is not something we were able to study. In addition, the assumption was made that there was no GDFT being used in 2011, whereas a survey published the same year indicates that approximately 5% of US anesthesiologists consistently use GDFT for high risk surgeries [9]. Further, this study assumes complete implementation of GDFT, which may be an unrealistic goal. The study by Kuper et al. [19] is the only real life and large scale GDFT implementation experience we know. They reported an adoption rate of 65%. Assuming a comparable adoption rate, our projected savings would have ranged between \$370-\$631 per patient. Finally, if costs and savings are of utmost importance for payers, profits (reimbursement – cost) are even more important for hospitals [30]. We did not have access to reimbursement information so that we were unable to project the impact of GDFT on hospital profits. Prospective studies are definitely required to assess the impact of GDFT implementation not only on costs but also on hospital profits since this may become the main driver for hospital adoption.

## Conclusion

Our study demonstrates the dramatic impact of postsurgical complications on costs (+172%) in patients undergoing major surgical procedures at UHC hospitals, and suggests significant savings if GDFT was to be implemented. Projected cost-savings per patient are the highest for abdominal aortic aneurysm open repair. However, taking into account the volume of surgeries, the highest total savings for the UHC are expected to come from the



implementation of GDFT in colectomies. Outside the UHC system, cost savings are necessarily institution specific, depending upon local case mix, morbidity rates, surgical costs and GDFT related costs. Individual institutions can use our methodology, on a local level, in their decision to pilot and implement GDFT. Finally, we believe this analysis provides the necessary data to warrant a large and prospective study on the economic impact of GDFT.

## **Key messages**

- We assessed the costs of postsurgical complications in 75,140 patients undergoing 10 major abdominal, orthopedic, vascular and urologic surgeries in order to predict potential savings with perioperative goal directed fluid therapy (GDFT).
- Post-surgical complications were responsible for a 172% increase in hospital costs (from \$17,408 to \$47,284 per patient).
- Projected cost-savings with the implementation of perioperative GDFT ranged between \$569 and \$970 per patient.
- Highest cost-savings per patient (\$1,523-\$2,599) were expected to come from the implementation of GDFT for abdominal aortic aneurysm open repair.
- Given the volume of surgeries, highest savings for the entire study population (\$16.6 M-28.3 M) were expected to come from the implementation of GDFT in patients undergoing colectomies.

## **Abbreviations**

GDFT, goal directed fluid therapy; UHC, University HealthSystem Consortium

## **Competing interests**

GRM received travel expense reimbursements and speaking fees from Edwards Lifesciences and FM is an employee of Edwards Lifesciences. However this manuscript does not support the use of any specific medical device. AA declares that she has no competing interests.

## **Authors' contributions**

GRM contributed to the design of the work; the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; and final approval of the version to be published. AA contributed to the acquisition of data for the work; drafting the work; and final approval of the version to be published. FM contributed to the conception of the work; the analysis, and interpretation of data for the work; revising the work critically for important intellectual content; and final approval of the version to be published. All authors read and approved the final manuscript.

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