1369-6998
doi:10.3111/13696998.2015.1017503

Article 0138.R1/1017503

Original article

Reduction in hospital costs and resource consumption associated with the use of advanced topical hemostats during inpatient procedures

Derek Martyn
Trinity Partners, LLC, Waltham, MA, USA

Richard Kocharian
Medical Affairs, Ethicon, Inc., Bridgewater, NJ, USA

Sangtaeck Lim
Global Health Economics and Market Access, Ethicon, Inc., Bridgewater, NJ, USA

Lisa M. Meckley
Gavin Miyasato
Katerina Prifti
Yajing Rao
Trinity Partners, LLC, Waltham, MA, USA

Jerome B. Riebman
Medical Affairs, Ethicon, Inc., Bridgewater, NJ, USA

Jillian G. Scaife
Yogesh Soneji
Trinity Partners, LLC, Waltham, MA, USA

Mitra Corral
Global Health Economics and Market Access, Ethicon, Inc., Bridgewater, NJ, USA

Address for correspondence:
Mitra Corral, Ethicon, Inc., 737 U.S. 22, Bridgewater, NJ 08807, USA.
Tel.: +1 908 218 2211; Fax: +1 908 218 5435;
mcorral3@ITS.JNJ.com

Keywords:
Hemostats – Hemostatic techniques – Blood transfusion – Healthcare costs – Blood loss – surgical

Accepted: 6 February 2015; published online: 26 March 2015
Citation: J Med Econ 2015; 1–8

Abstract

Objective:
The use of hemostatic agents has increased over time for all surgical procedures. The purpose of this study was to evaluate the newer topical absorbable hemostat products Surgicel* Fibrillar† and Surgicel SNoW‡ (Surgicel advanced products, abbreviated as SAPs) compared to the older product Surgicel Original (SO) with respect to healthcare resource use and costs in procedures where these hemostats are most commonly used.

Research design and methods:
A retrospective analysis of the Premier hospital database was used to identify adults who underwent brain/cerebral (BC), cardiovascular (CV: valve surgery and coronary artery bypass graft) and carotid endarterectomy (CEA) between January 2011–December 2012. Among these patients, those treated with SAPs were compared to those treated with SO. Propensity score matching (PSM) was used to create comparable groups to evaluate differences between SAPs and SO.

Main outcome measures:
The primary end-points for this study were length of stay (LOS), all-cause total cost, number of intensive care unit (ICU) days, ICU cost, transfusion costs and units, and SO/SAP product units per discharge.

Results:
Matched PSM created patient cohorts for SO and SAPs were created for BC ($n = 758$ for both groups), CV ($n = 3388$ for both groups), and CEA ($n = 2041$ for both groups) procedures. Patients that received SAPs had a 14–16% lower mean LOS for each procedure compared to SO, as well as 12–18% lower total mean cost per discharge for each procedure ($p < 0.02$ for all results). Mean ICU costs for SAPs were also lower, with a reduction of 20% for BC and 19% for CV compared to SO ($p < 0.01$). However, for CEA, there was no statistically significant difference in ICU costs for SAPs compared to SO.

Conclusions:
In a retrospective hospital database analysis, the use of SAPs were associated with lower healthcare resource utilization and costs compared to SO.

*Surgicel is a registered trademark of Ethicon, Inc., Somerville, NJ
†Fibrillar is a trademark of Ethicon, Inc, Somerville, NJ
‡SNoW is a trademark of Ethicon, Inc, Somerville, NJ

Introduction

Bleeding is a risk in almost all surgical procedures. Difficult to control, poorly controlled or uncontrolled bleeding can occur in a considerable proportion of surgeries, e.g., nearly 50% of patients undergoing cardiac surgery experienced a bleeding-related complication[1]. These bleeding episodes can have severe negative repercussions for patients, including higher rates of transfusion due to bleeding, increased length of stay, and increased costs by as much as 93%[1]. Uncontrolled bleeding is also associated with increased mortality rates[2], and the need for a patient to undergo a transfusion can significantly impact patient outcomes and cost of care due to this factor alone[3].

Adjunctive hemostats are used to treat bleeding in the surgical setting. Hemostats provide a matrix to assist the clotting process and serve as a barrier to bleeding[4]. On average, ~30% of surgeries include the use of a hemostatic agent[5]. Adjunctive hemostats include a wide variety of materials such as gelatin, collagen, cellulose, polysaccharide spheres[4], and oxidized regenerated cellulose. All Surgicel hemostats are made from a plant-derived oxidized regenerated cellulose (ORC). The first Surgicel hemostat was Surgicel Original (SO), a sheer woven ORC, which was approved by the FDA in 1959 and has been used in >100 million surgical procedures worldwide[6]. Surgicel Fibrillar, an ORC with a layered fibrous structure that can be pulled apart or formed into tufts, and Surgicel SNoW, a non-woven ORC which can conform to irregular surfaces, are classified as Surgicel advanced products (SAPs), and were approved in 1996 and 2012, respectively[7]. Studies have demonstrated that Surgicel SNoW and Surgicel Fibrillar have faster times to hemostasis (43% and 33% faster, respectively) compared to SO[8,9]. Due to the improved hemostatic action of SAPs, we hypothesized that they would be associated with lower costs and resource utilizations compared to SO.

The purpose of this study was to assess whether SAPs are associated with a change in resource utilization and medical costs compared to SO. The differences in these outcomes between SAPs and SO were assessed in the procedure groupings of brain/cerebral operations (BC), cardiovascular surgeries (CV), and carotid endarterectomy (CEA). These procedures were selected because they are common procedures, with more than 30,000 discharges each for BC, CV, and CEA in the database for the analyzed time period, and a Surgicel product was used in at least 20% of discharges for each procedure.

Patients and methods

Study design

This was a retrospective, observational analysis of BC, CV, and CEA procedures from the US hospital database maintained by Premier evaluating the clinical and economic outcomes of patients whose discharge data included the use of SO or SAPs.

Data source

The Premier hospital database (referred to as the Premier database) was used for this analysis. Premier is a consortium of US community and teaching hospitals that are non-profit and non-governmental, with ~6 million discharges annually. The Premier database covers ~25% of all hospital discharges in the US annually[10]. The database consists of chargemaster data, which contains discharge-level resource utilization, diagnoses, and procedures information in addition to patient demographic and hospital characteristics. This database contains a day of service-stamped log containing all billed items, laboratory, diagnostic, and therapeutic services, and medications during the hospital stay. The Premier database was chosen due to its broad coverage of US inpatient procedure data, allowing for generalizability to the entire US hospital market, and the ability to define the patient population and measure outcomes of interest to this study.

Study cohort

Adult patients (18 years of age or older) with a hospitalization discharge from the Premier database between January 1, 2011 and December 31, 2012 were evaluated. Discharges for the procedure groupings of BC, CV, and CEA were eligible for inclusion in the study if utilization of one of the three Surgicel adjunctive hemostat products of interest, Surgicel Original (SO), Surgicel Fibrillar, or Surgicel SNoW, was identified in the charge code data (hemostat hospital charge codes are available upon request). Hospitalizations were excluded if SO was used in combination with Surgicel Fibrillar and/or Surgicel SNoW, or if Surgicel Fibrillar and Surgicel SNoW were used concomitantly. Any discharges involving Surgicel Nu-Knit* were also excluded due to relatively low utilization (≤2% of discharges in BC, CV, and CEA) compared to SO and SAPs, and because it tends to be used in clinically different settings (i.e., heavier bleeding, non-laparoscopic procedures). BC, CV, and CEA hospitalization were identified on the basis of ICD-9 procedure and CPT codes (see Supplementary Table 1). Product utilization was identified on the basis of charge codes. Patients could contribute more than one procedure to the cohort.

Outcomes

The primary end-points for this study were length of stay (LOS), all-cause total cost, number of intensive care unit

*Nu-Knit is a trademark of Ethicon, Inc, Somerville, NJ

(ICU) days, ICU cost, transfusion costs and units, hospital mortality, and SO/SAP product units per discharge. Length of stay and total cost for each hospitalization were abstracted from the dataset as directly supplied by the hospital. ICU days were defined as the number of days any ICU room and board charge code was present during a hospitalization. ICU cost was the sum of all of the ICU room and board charges during the hospitalization. Transfusion standard charge codes for transfused blood products (red cell, whole blood or platelets) were used to identify patient discharges with transfusion cost and unit data. Not all hospitals report transfusion standard charge codes; therefore, the proportion of patients in the transfusion analysis was a sub-set of all patients that received transfusions. In-hospital mortality was assessed using discharge status. SO and SAP units per discharge were defined as the count of SO and SAP units per discharge.

Analysis

Cohorts were divided according to the use of SO or SAPs. The SAP cohort consisted of Surgicel Fibrillar and Surgicel SNoW, which were grouped together in this analysis due to their relative similarity in hemostasis time[11]. All analyses were performed separately for the indications of BC, CEA, and CV. Descriptive statistics were calculated for demographic, clinical, and hospital characteristics.

To reduce or eliminate the effect of treatment-selection bias, matched pairs of SO and SAP patients were created using a propensity score matching (PSM) approach[12]. PSM is frequently used in the medical literature as a means to adjust for confounding factors when using observational data to estimate the effect of treatments on outcomes[13]. Once matched cohorts are created, several outcomes can be studied; this provides an advantage over creating independent regression models for each outcome because there is less concern about model misspecification[14]. In this study, PSM was used to create matched patient cohorts based on their propensity to be treated with the product. To estimate a patient's propensity for particular treatment, logistic regression models were fit, regressing on patient and hospital characteristics, specifically, age, ethnicity, gender, comorbidities (see Supplementary Table 2 for codes), pre-existing bleeding condition (see Supplementary Table 3 for codes), teaching/non-teaching hospital status, hospital census region, urban/rural hospital location, and the use of additional hemostats during the procedure. Within each matched patient pair, the types of additional adjunctive hemostats, e.g., gelatin, thrombin, and flowables, were required to be identical. Separate models were fit for each procedure. Patients were matched using a 1:1 greedy matching algorithm[15], and standardized differences for all patient and hospital characteristics were calculated to assess the balance of matched patient characteristics.

Standardized differences of demographic and patient characteristics between SO and SAP cohorts were calculated before and after PSMs to help assess the efficacy of the PSMs. After the matched cohorts were created, differences between SO and SAP were calculated for all outcome measures: LOS, total cost, ICU days, ICU costs, transfusion costs and units, and SO/SAP units per discharge for each indication. Statistical differences between SO and SAP for LOS were assessed with Wilcoxon signed rank sum tests and the Wilcoxon-Mann-Whitney test was used for the ICU days. Statistical differences for cost outcomes were calculated using Student's *t*-test. Chi-squared tests were used to evaluate transfusion units. Transfusion costs and units were evaluated only for patients treated in hospitals, where this information was recorded. A threshold of 30 discharges each in the SO and SAP groups with unit and cost data was set for the evaluation of transfusions. Fisher's exact test was used to evaluate differences in mortality.

Statistical analysis was performed using SAS 9.2 (SAS Institute, Cary, NC).

Results

Cohort characteristics

A total of 30,957 patients with a BC discharge during the 2-year study period were identified in the Premier hospital database. Of these, 5919 were treated with SO and 1228 treated with SAPs and met the inclusion criteria in the analysis. For the CV discharge analysis, 107,667 patients were identified during the study period. Of these, 12,318 SO and 6525 SAP patients from the Premier hospital database were identified as eligible for the study. A total of 30,480 CEA discharges were identified during the 2-year study period; 5064 were treated with SO and 2595 were treated with SAPs (Table 1).

Propensity score matching produced cohorts of 1516 for BC (match rate of 62%), 6776 for CV (match rate of 52%), and 4082 for CEA (match rate of 79%), with patients divided equally between SO and SAPs. After matching, most standardized differences were 0.10 or lower for demographic, co-morbid/pre-existing, or hospital characteristics (Table 1).

Length of stay

After propensity score matching, utilization of SAPs was associated with a 14–16% reduction in mean LOS for all three procedures (see Figure 1). For BC patients, SAPs were associated with a significant reduction in LOS from 10.4 to 8.9 days for a difference of 1.5 days ($p = 0.013$). The reduction in LOS for SAPs compared to SO in CV

Table 1. Patient characteristics by procedure type.

	Brain/cerebral operations					Cardiovascular					Carotid endarterectomy				
	Surgicel Original		Surgicel Advanced		SD*	Surgicel Original		Surgicel Advanced		SD*	Surgicel Original		Surgicel Advanced		SD*
	n	%	*n*	%		*n*	%	*n*	%		*n*	%	*n*	%	
	758		758			3388		3388			2041		2041		
Demographics															
Age (mean years)	56.6		57.8		0.07	65.5		65.9		0.04	71.8		70.8		−0.11
Male	463	61%	426	56%	−0.10	2139	63%	2226	66%	0.05	1176	58%	1179	58%	0.00
Ethnicity															
Caucasian	547	72%	539	71%	−0.02	2478	73%	2615	77%	0.09	1723	84%	1804	88%	0.12
African American	83	11%	93	12%	0.04	462	14%	391	12%	−0.06	111	5%	113	6%	0.00
Hispanic	11	1%	5	1%	−0.08	13	0%	10	0%	−0.02	1	0%	0	0%	−0.03
Other	117	15%	121	16%	0.01	435	13%	372	11%	−0.06	206	10%	124	6%	−0.15
Comorbidities															
AIDS	–	–	–	–	–	2	<1%	0	0%	−0.03	–	–	–	–	–
Any malignancy	194	26%	209	28%	0.04	–	–	–	–	–	–	–	–	–	–
Chronic pulmonary dis.	–	–	–	–	–	1084	32%	1081	32%	0.00	540	26%	512	25%	−0.03
Congestive heart failure	–	–	–	–	–	1042	31%	952	28%	−0.06	–	–	–	–	–
Hemiplegia or paraplegia	–	–	–	–	–	24	1%	17	1%	−0.03	–	–	–	–	–
Hypertension	–	–	–	–	–	2655	78%	2679	79%	0.02	1666	82%	1695	83%	0.04
Liver disease	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Metastatic solid tumor	–	–	–	–	–	4	<1%	0	0%	−0.05	–	–	–	–	–
Obesity	89	12%	62	8%	−0.12	–	–	–	–	–	–	–	–	–	–
Renal dialysis	–	–	–	–	–	667	20%	576	17%	−0.07	74	4%	61	3%	−0.04
Hospital characteristics															
Census region															
Northeast	90	12%	88	12%	−0.01	436	13%	438	13%	0.00	75	4%	95	5%	0.05
Midwest	102	13%	113	15%	0.04	715	21%	802	24%	0.06	451	22%	494	24%	0.05
South	444	59%	448	59%	0.01	1867	55%	1601	47%	−0.16	1334	65%	1328	65%	−0.01
West	122	16%	109	14%	−0.05	370	11%	547	16%	0.15	181	9%	124	6%	0.11
Bed size															
<200	14	2%	12	2%	−0.02	84	2%	65	2%	−0.04	110	5%	104	5%	−0.01
200–400	202	27%	295	39%	0.26	1389	41%	1664	49%	0.16	1201	59%	1091	53%	−0.11
>400	542	72%	451	59%	−0.25	1915	57%	1659	49%	−0.15	730	36%	846	41%	0.12
Affiliation															
Teaching	350	46%	356	47%	0.02	1612	48%	1338	39%	−0.16	646	32%	631	31%	−0.02
Non-teaching	408	54%	402	53%	−0.02	1776	52%	2050	61%	0.16	1395	68%	1410	69%	0.02
Location															
Urban	–	–	–	–	–	3067	91%	3029	89%	−0.04	1686	83%	1691	83%	0.01
Rural	–	–	–	–	–	321	9%	359	11%	0.04	355	17%	350	17%	−0.01

*The '–' indicates that the propensity score matching process did not incorporate that characteristic.

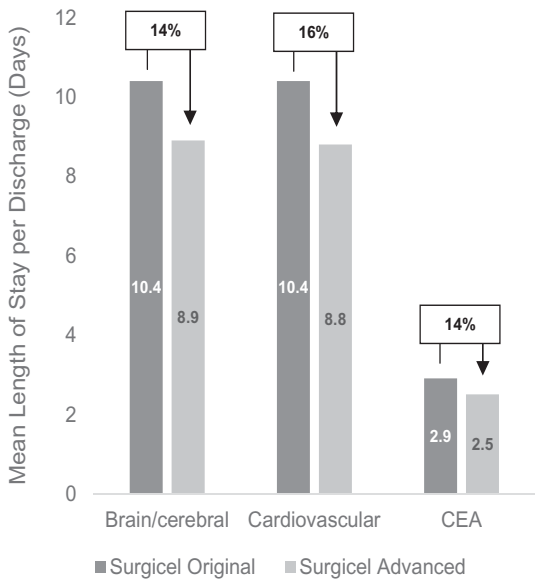

Figure 1. Mean length of stay per discharge for the Surgicel Original and Advanced cohorts by procedure type. All differences statistically significant at the $p<0.02$ level; p-values assessed with non-parametric Wilcoxon signed rank sum test.

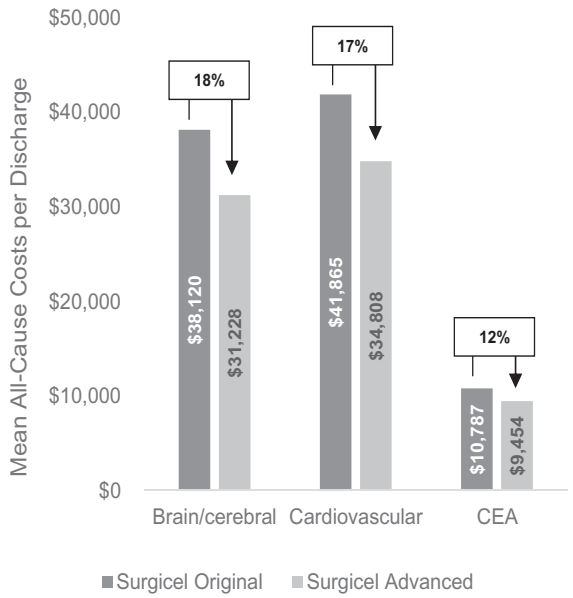

Figure 2. Mean all-cause costs per discharge for the Surgicel Original and Advanced cohorts by procedure type. All differences statistically significant at the $p<0.001$ level; p-values assessed with paired t-tests.

patients was similar to BC, with a 1.7 day shorter LOS (10.4 days for SO, 8.8 days for SAPs, $p<0.001$). CEA procedures are typically not associated with lengthy inpatient stays for post-operative recovery, thus the LOS for SO was 2.9 days and for SAPs was 2.5 days for a statistically significant reduction of 0.4 days ($p<0.001$); this reduction is similar proportionally to the reductions in LOS for BC and CV.

All-cause cost per discharge

In all three procedures, utilization of SAPs was associated with statistically significant lower mean all-cause costs compared to SO, with the lower mean costs ranging from 12% for CEA to 18% for BC (see Figure 2). For BC and CV procedures, which had high mean all-cause costs per discharge, the decrease in mean cost was $6891 for BC procedures and $7056 for CV procedures ($p<0.001$ for both BC and CV). Mean all-cause costs in the CEA procedure group were also lower for the SAP cohort compared to SO ($9454 and $10,787, respectively, $p<0.001$). While the decrease in per discharge mean cost was only $1333 for CEA, the difference in cost between SAPs and SO was proportionally similar to the cost differences observed for the BC and CV procedures.

ICU costs and length of stay

For the three procedures evaluated in this study, the majority of patients' hospital stays included a proportion of their admission in the ICU (see Table 2). BC patients with SAPs had 1.1 fewer ICU days compared to SO ($p=0.017$), comprising 76% of the reduction in total LOS, and $2147 lower ICU costs ($p=0.002$), which represented 31% of the decrease in all-cause costs compared to SO. CV patients treated with SAPs had 0.6 fewer ICU days ($p=0.743$) and $1776 lower costs ($p<0.001$) compared to SO, which comprised 35% and 25%, respectively, of the overall difference in LOS and all-cause costs. In contrast to BC and CV patients, the utilization of SAPs in CEA patients had negligible effect on days in the ICU, with only 0.1 ICU day ($p=0.666$) and $147 ($p=0.169$) ICU cost difference between the patients treated with SAPs and SO.

Table 2. ICU-related days and costs for the Surgicel Original and Advanced cohorts by procedure type.

	Brain/cerebral	Cardiovascular	CEA
n (% of cohort sample)			
Original	700 (92%)	2651 (78%)	1492 (73%)
Advanced	678 (89%)	2763 (82%)	1226 (60%)
Mean ICU days			
Original	5.9	5.5	1.6
Advanced	4.8	4.9	1.7
p-value*	0.017	0.743	0.666
Mean ICU costs			
Original	$10,796	$9570	$2491
Advanced	$8,649	$7794	$2344
p-value**	0.002	<0.001	0.169

*p-value assessed with non-parametric Wilcoxon-Mann-Whitney test.
**p-value assessed with unpaired t-test.

Table 3. Transfusion units and costs for the Surgicel Original and Advanced cohorts with cardiovascular procedures.

	Original	Advanced products	% Difference (*p*-value)
n	111	176	N/A
Mean units of transfused blood per discharge*	5.15	3.95	23% (0.639)
Mean cost of transfused blood per discharge**	$1102	$678	38% (0.029)

*p-value assessed with χ^2 test.
**p-value assessed with Wilcoxon-Mann-Whitney test.

Transfusions

There were only a total of 324 patients with transfusions across all three procedures in our cohorts. The transfusion analysis was restricted to CV patients, in which there were 287 discharges that included a transfusion with unit and cost data for both hemostat types (see Table 3); this was the only group with more than 30 discharges each for SAPs and SO with unit and cost data. Mean transfused blood product usage was 23% lower in the SAP group (3.95 units per discharge) compared to the SO group (5.15 units per discharge, $p = 0.639$). While the difference in units was not statistically significant, the difference in costs, $678 for SAPs and $1102 for SO, was statistically significant ($p = 0.029$). The mean transfused blood product cost per discharge was 38% lower for the SAP group compared to the SO group.

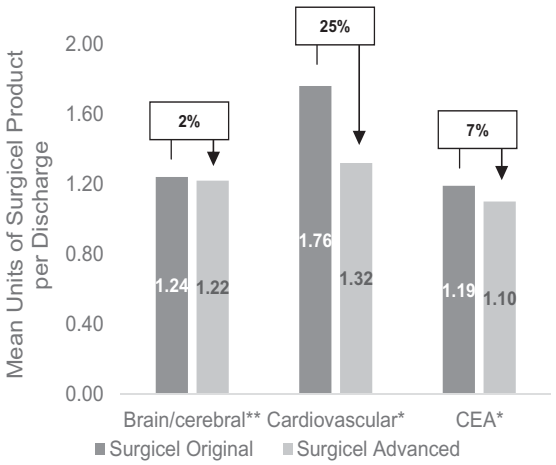

Figure 3. Mean units per discharge of Surgicel Original and Advanced use by procedure type. *Differences statistically significant at the $p < 0.001$ level. **Not statistically different; *p*-values assessed with non-parametric Wilcoxon signed rank sum test.

Mortality status

The proportion of discharges that ended in death was not statistically significantly different between SAP and SO patients for BC or CV. The proportion of BC patients where SAP was used who died in the hospital was 7.0% compared to 7.9% for SO patients ($p = 0.494$). The death rate was lower for CV procedures, 2.2% and 2.8% for SAP and SO patients, respectively ($p = 0.073$). CEA patients had the lowest death rate of the procedures evaluated, and the SAP patients had a significantly lower mortality rate than SO patients (0.1% compared to 0.7%, $p = 0.007$).

Units of Surgicel product per discharge

The mean number of Surgicel units per discharge was significantly lower for SAPs compared to SO for both CV and CEA procedures. This difference was particularly pronounced in the CV procedure group, where mean SAP and SO per discharge units were 1.32 and 1.76, respectively ($p < 0.001$, see Figure 3). The mean difference between SAP and SO hemostats was much smaller for CEA (mean SAP and SO units per discharge of 1.10 and 1.19, respectively), although this difference was still statistically significant ($p < 0.001$). In BC patients, mean units per discharge utilization of SAP and SO products were similar (1.22 and 1.24, respectively, $p = 0.905$).

Discussion

We compared patients treated with Surgicel Fibrillar and Surgicel SNoW (SAPs) to Surgicel Original (SO) on costs and resource utilization metrics such as LOS, ICU utilization, units of hemostat product, and transfusions using observational discharge-level data from a hospital charge-master dataset. After creating comparable SAP and SO groups using propensity score matching, our study found that patients with BC, CV, and CEA procedures treated with SAPs had shorter LOS and lower associated costs than patients treated with SO. BC was found to have statistically significant differences in ICU days and costs that favored SAP-treated patients; CV also had lower ICU costs for the SAP group compared to SOs, and both CV and CEA had lower product utilization for SAPs compared to the SO group as measured by units per discharge. The analysis of blood transfusion units and costs was impacted by only 3% of discharges having transfusions with appropriate coding detail to evaluate transfusion

units and costs. Only CV had an adequate sample of discharges with blood transfusion units and cost data, and our analysis found that the mean number of transfusion units were not statistically significantly different. However, cost of the blood products was significantly lower for the SAP-treated patients.

While the list price of SAPs is more on a per-unit basis compared to SO ($74–$206 for SAPs vs $29–$96 for SO)[16], the associated reduction in resource utilization resulted in net lower costs of ~$7000 for BC and CV procedures and $1300 for CEA. Costs are closely tied to LOS, with patients who have higher LOS also having higher costs. Much of the reduction in cost is due to the 14–16% reduction in average LOS. On a per-day basis, the use of SAPs was associated with cost reductions of over $4000 for BC and CV, and approaching $3500 for CEA. Because LOS and costs may be closely associated with underlying characteristics of the hospitals, rather than the hemostat used, we performed a post-hoc analysis on the sample including only procedures performed in hospitals where both SO and SAPs were used. In that subgroup analysis, the results for ICU, LOS, and costs did not change substantially, indicating that differences in hospital utilization of SAPs and SO were not driving results.

Overall, in our study population, the average LOS for CV patients was ~9.6 days; this is similar to the 8.7 days that Stokes *et al.*[1] found in a 2006–2007 study focused on bleeding in cardiovascular patients. This study found that bleeding complications during surgery were associated with significantly increased cost and LOS. Stokes *et al.*[1] also found that bleeds in cardiac and vascular surgeries increased the length of stay for the procedure by 4.8 and 9.3 days, respectively, and increased total cost of the surgery by over $10,000 for cardiac and $17,000 for vascular surgeries. More recently, Wright *et al.*[5] found that the use of hemostatic agents has increased rapidly between 2000–2010 for major surgeries. While studies have been conducted on the reduction of bleeding due to hemostat use, or bleeding's impact on costs and resource utilization, there have been a limited number of studies of the impact of hemostats on both costs and outcomes. A meta-analysis of studies focused on fibrin sealant use did not find a significant difference in the length of hospital stay compared to no adjunctive hemostat use[17]. To our knowledge, our present study is the first to evaluate the resource utilization and overall costs associated with the use of oxidized regenerated cellulose adjunctive hemostats.

Given the concerns about healthcare costs and the desire to treat patients in an evidence-based manner, this study provides evidence to suggest that, in specified patient populations, the use of SAPs rather than SO may improve health outcomes and reduce costs. Within the Premier database, there were 1516 BC, 6776 CV, and 4082 CEA patients who received a Surgicel adjunctive hemostat with similar clinical profiles, i.e., the patients who were included in the PSMs. Utilization of the SAPs was associated with over 1100 cumulative fewer days in hospital for BC patients; in CV and CEA, the reduced total LOS was greater than 5700 and 800 days, respectively. Aggregate cost reductions amounted to $5.2 million for BC, $23.9 million for CV, and $2.7 million for CEA. If all of the SO cohort was converted to SAPs, equivalent cumulative cost and resource utilization reductions could be expected to occur. It should be noted that this study only evaluated Surgicel products, so it is unclear how SAPs compare to other types of adjunctive hemostats. Future research should explore the health outcomes, resource utilization, and cost differences for a variety of different adjunctive hemostat types.

Limitations

All observational, retrospective studies of secondary data have inherent limitations. Not all of the factors that influence a physician's choice of products to treat specific patients are available in the dataset. Additionally, because the patients were not randomized, we cannot be certain that there were no inherent differences between the patients receiving SAPs and SO that influenced patient outcomes. However, PSMs were used to create similar groups for comparison. While PSMs cannot control for unmeasured characteristics and, thus, is less powerful than randomization, on the basis of observable characteristics, the patient populations were made comparable, as measured by improvements in standardized differences for all characteristics. There are also limitations to the charge-master data within the Premier database. The data do not capture hospital re-admissions to other facilities with different medical record systems, non-hospital-based office visits, and also do not include all outpatient data for all hospitals that submit inpatient data. However, these limitations are not relevant to the current study, since all outcomes measured occurred during the hospital stay and did not include physician office visits. Additionally, it is unclear whether treatment patterns and outcomes differ between hospitals that are within or outside of the Premier hospital database and whether these hospitals are representative, although these results are most likely generalizable to many patients across the US, as ~25% of all hospital discharges are from a hospital within the Premier database. Finally, as with all claims and charge-master data, coding errors or omitted procedure/product codes could lead to misclassification of patients and potential bias in the results. However, since these data are used for payment, there is a strong incentive for accuracy.

Finally, it is unclear whether the benefits found in using SAPs in this study can be generalized across other procedures not evaluated in this study. Because the procedures evaluated (BC, CV, and CEA) represent a broad range of

different types of procedures, this study demonstrates that SAP use is associated with beneficial outcomes under a variety of circumstances. Additionally, these procedures are the most common for Surgicel use, and thus are the most relevant procedures to evaluate.

Conclusions

In conclusion, our study found that Surgicel advanced products (SAPs) are associated with reduced patient length of stay and all-cause costs compared to Surgicel Original (SO) in three common procedure groupings. The decreased all-cause costs, which were as high as ~$7000 for brain/cerebral and cardiovascular surgeries, more than offset the incremental increased cost associated with the use of SAPs compared to SO ($50–$150 depending on hemostat unit size). This study indicates that SAPs may have the potential improve patient outcomes while reducing the economic burden to hospitals, representing good economic value.

Transparency

Declaration of funding
This study was funded by Ethicon, Inc.

Declaration of financial/other relationships
RK, SL, JR, and MC are all shareholders of Johnson & Johnson and employees of Ethicon, Inc. DM, LM, GM, KP, YR, JS, and YS are all consultants for Johnson & Johnson. JME peer reviewers on this manuscript have no relevant financial or other relationships to disclose.

References

1. Stokes M, Ye X, Shah M, et al. Impact of bleeding-related complications and/or blood product transfusions on hospital costs in inpatient surgical patients. BMC Health Serv Res 2011;11:135
2. Marietta M, Facchini L, Pedrazzi P, et al. Pathophysiology of bleeding in surgery. Transplant Proc 2006;38:812-14
3. Shander A, Hofmann A, Ozawa S, et al. Activity-based costs of blood transfusions in surgical patients at four hospitals. Transfusion 2010;50:753-65
4. Gabay M, Boucher BA. An essential primer for understanding the role of topical hemostats, surgical sealants, and adhesives for maintaining hemostasis. Pharmacotherapy 2013;33:935-55
5. Wright JD, Ananth CV, Lewin SN, et al. Patterns of use of hemostatic agents in patients undergoing major surgery. J Surg Res 2014;186:458-66
6. Food and Drug Administration: Department of Health E, and Welfare. NDA 12159. Silver Spring, MD: Food and Drug Administration: Department of Health, Education, and Welfare, 1959. Available at: http://www.ethicon360.com/sites/default/files/JJ%20Letter.pdf [Last accessed April 30, 2014]
7. US Food and Drug Administration. Premarket Approval (PMA). Silver Spring, MD: US Food and Drug Administration, 2014. Available at: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPMA/pma.cfm [Last accessed April 30, 2014]
8. Ethicon, Inc. a Johnson & Johnson Company. Surgicel Fibrillar Absorbable Hemostat. Somerville, NJ: Ethicon US, LLC, 2014. Available at: http://www.ethicon360.com/products/surgicel-fibrillar-absorbable-hemostat [Last accessed April 30, 2014]
9. Ethicon, Inc. a Johnson & Johnson Company. Surgicel SNoW Absorbable Hemostat. Somerville, NJ: Ethicon, US LLC, 2014. Available at: http://www.ethicon360.com/products/surgicel-snow-absorbable-hemostat [Last accessed April 30, 2014]
10. Premier, Inc. Mission and vision. Charlotte, NC: Premier, Inc, 2014. Available at: https://www.premierinc.com/wps/portal/premierinc/public/aboutpremier/missionvision [Last accessed May 5, 2014]
11. Hutchinson R, George K, Johns D, et al. Hemostatic efficacy and tissue reaction of oxidized regenerated cellulose hemostats. Cellulose 2013;20:537-45
12. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika 1983;70:41-55
13. Austin PC. A critical appraisal of propensity-score matching in the medical literature between 1996 and 2003. Stat Med 2008;27:2037-49
14. Seeger JD, Williams PL, Walker AM. An application of propensity score matching using claims data. Pharmacoepidemiol Drug Saf 2005;14:465-76
15. Steiner PM, Cook D. Propensity matching and propensity scores. In: Little TD, editor. The Oxford handbook of quantitative methods in psychology. 1. New York: Oxford University Press, 2013
16. Ethicon, Inc. a Johnson & Johnson Company. 2014 List prices for Surgicel family of topical absorbable hemostats. Somerville, NJ: Ethicon, Inc; 2014
17. Carless PA, Henry DA, Anthony DM. Fibrin sealant use for minimising perioperative allogeneic blood transfusion. Cochrane Database Syst Rev 2003;2:CD004171

Notice of Correction:
The version of this article published online ahead of print on 26 Mar 2015, contained an error on page 2. On avarage ~70% of surgeries include the use of hemostatic agent. The percentage "70%" should have read "30%". The error has been corrected for this version.