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*Qual. Saf. Health Care* 2009;18;360-368  
doi:10.1136/qshc.2007.025056

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# ProvenCare: quality improvement model for designing highly reliable care in cardiac surgery

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Accepted 14 July 2008

## ABSTRACT

**Objective:** To test whether an integrated delivery system could, through the application of process redesign methodology and reliability science, implement multiple evidence-based medical practices across the continuum of care for a specific surgical intervention and deliver these practices consistently.

**Methods:** The programme—*ProvenCare*—had three components: establishing best practices for elective coronary artery bypass graft (CABG) patients; assembling a multidisciplinary team to “hardwire” these best practices into everyday workflow; and implementing the programme with real-time data collection, feedback and focused redesign to reach high reliability. Surgeons reviewed all class I and IIa 2004 ACC/AHA guidelines for CABG surgery and translated them into 19 clinically applicable recommendations. A frontline multidisciplinary team “hardwired” these, resulting in 40 measurable process elements. Feedback of gaps in care was given and the process redesigned as needed. Clinical outcome data on consecutive elective CABG patients seen in the 12 months pre-intervention were then compared with a post-intervention group.

**Results:** Initially, 59% of patients received all 40 elements. At 3 months, compliance reached 100%, fell transiently to 86% and then reached 100% again, and was sustained for the remainder of the study. The overall trend in reliability was significant ( $p = 0.001$ ). 30-day clinical outcomes showed improved trends in 8/9 measured areas (eg, patient readmissions to ICU decreased from 2.9% to 0.9% and blood products usage decreased from 23.4% to 16.2%). Operative mortality decreased to zero, but only likelihood of discharge was significant ( $p = 0.033$ ). Frequency and length of readmissions fell, as did mean hospital charges.

**Conclusion:** Frontline medical care providers, led by process design specialists, can successfully redesign episodic processes to consistently deliver evidence-based medicine, which may improve patient outcomes and reduce resource use.

“Quality is never an accident. Quality is always the result of intelligent effort. It begins with the intent to make a superior thing.”

John Ruskin, English critic, essayist and reformer (1819–1900)

Specialty medical societies provide an excellent forum to codify knowledge of the best evidence-based medical practices for a specific health condition. The American College of Cardiology/American Heart Association (ACC/AHA) guidelines for coronary artery bypass graft surgery (CABG)<sup>1</sup> and the Society of Thoracic Surgery (STS) guidelines<sup>2</sup> provide the multidisciplinary

cardiac surgical team with a host of recommended interventions based on evidence, ranging from randomised clinical trials to retrospective studies. What these publications lack is a “how-to” guide to embed these practices into the everyday work flow of a busy cardiac surgery practice. Langley *et al*<sup>3</sup> have shown quality improvement through process redesign and Nolan *et al*<sup>4</sup> introduced the concept of high reliability. Both approaches help address the gap between authoritative recommendations and actual clinical practice.

## THE PROBLEM

Our cardiothoracic surgery department had no systematic process for the evaluation and incorporation of evidence-based medicine (EBM) into acute episodic clinical practice. Regular forums for interdisciplinary patient care planning were not established. Individual surgeons would incorporate EBM into their own practice, but these practices might (or might not) be adopted by their colleagues. This method resulted in inconsistent application of EBM across the surgical service line, variation in care delivered to the patient, and variation in related outcomes. Along the clinical path of a CABG patient, individual microsystems had implemented improvement within their area, but similar work had not occurred between microsystems, perpetuating the silo-ed approach to care delivery. Also, there was steadily increasing severity of comorbid conditions among patients referred for CABG surgery. Inconsistent clinical practice was present from the preoperative phase through the entire continuum of care (preoperative evaluation through postoperative rehabilitation) and varying practice patterns increased the probability of error.

## PURPOSE

This paper describes the process redesign methodology and use of reliability science that allowed us to decrease morbidity/mortality and readmission rates for elective CABG patients by incorporating 19 class I and IIa best practices from the ACC/AHA 2004 guideline update for CABG, which we have translated into 40 trackable process elements. Through this process redesign we have successfully learned how to provide these 40 best practice elements 100% of the time for every patient.

## METHODS

### Setting

Founded in 1915, Geisinger Health System (“Geisinger”) is a large integrated healthcare delivery system located in rural central and north-eastern Pennsylvania serving a population of 2.6

million in 41 of the state's 67 counties. The system's physician group practice (Geisinger Clinic) has nearly 650 physicians. This includes approximately 200 primary care physicians in 38 community practice locations; the balance are specialists. Geisinger has three tertiary/quaternary medical centres and a health insurance plan, Geisinger Health Plan, with approximately 210 000 members. Nearly 500 medical students, residents and fellows, as well as other clinical training programmes, reflect the system's commitment to education. Basic science and translational research—including the design and dissemination of new models of healthcare delivery—help focus the system's clinical mission. Of particular note, early adoption and system-wide deployment of an electronic health record (EHR) beginning in 1995 has placed Geisinger in the forefront of health informatics—a key to successful large-scale clinical process redesign. The cardiothoracic surgery department consisted of five surgeons performing elective CABG at two hospitals; later another surgeon in our third hospital initiated the same process. The department has consistently ranked in the top decile for performance as reported by the Pennsylvania Health Care Cost Containment Council (PHC4) and the STS database.

### The intervention

In August 2005, the concept of delivering all evidence-based recommended care to each elective CABG patient began to evolve and became known as *ProvenCare*. The goal was to create a replicable process of incorporating multiple EBM practices into acute episodic surgical interventions. A steering committee was formed, composed of senior leaders and a process improvement specialist. A cardiac surgery physician extender was assigned within the clinical effectiveness division as the clinical improvement specialist to facilitate and coordinate the initiative. Guided by the system's process improvement leaders, the intervention progressed through three phases over 6 months. At the same time, multiple efforts were underway to improve the delivery of safe, effective care to patients, guided by the Joint Commission's national patient safety goals<sup>5</sup> and the Institute for Healthcare Improvement's 100,000 lives initiative.<sup>6</sup> In addition, there was a major focus on the active engagement of patients and families from the decision to have surgery to enrolment in postoperative rehabilitation and secondary disease prevention.

The *ProvenCare* programme was developed and implemented in three phases:

1. review and validation of best practice evidence;
2. redesign of the process;
3. implementing the new process.

A detailed description of each phase follows.

#### Phase 1: evidence

ACC/AHA class I and IIa recommendations for CABG were presented at the first of a series of consensus-building meetings involving the cardiac surgeons from each Geisinger institution. Recommendations that were currently practised by the majority of surgeons were agreed on as the starting point. Recommendations not currently practised, ones that required additional evaluation of the scientific evidence, or ones lacking clear clinical application were assigned to a surgeon "champion". This champion completed an expanded literature review and became the content expert in a facilitated discussion around their assigned recommendation. Facilitated discussion of published evidence and local practice was essential in achieving physician consensus and "translating" authoritative recommendations into

local clinical application (box 1). The result was 19 clinically applicable recommendations (table 1) that had 40 measurable process elements (fig 1).

#### Phase 2: process redesign

Effective microsystems are designed with the patient in mind.<sup>7</sup> Our process redesign began with that fundamental principle. Secondly, understanding that clinical microsystems are the building blocks of health systems, our intent was to further foster a productive interaction between informed, activated patients and prepared, proactive staff.<sup>8</sup>

A multidisciplinary improvement team (comprised of a physician, cardiac surgery physician assistant, critical care registered nurse, operating theatre registered nurse, cardiac rehabilitation technician, electronic health record programmer, and clinical process improvement specialists) was formed at the two institutions and weekly joint improvement meetings were established. The team members' work schedule continued in addition to the redesign process. A videoconference format was adopted that greatly facilitated communication between these teams and helped eliminate non-productive travel time between sites. Team coaching, provided by the clinical process improvement specialist, had an important role in the process redesign. This included brainstorming sessions, introduction of reliability science concepts and project discipline in order to keep the team members engaged and the time spent in redesign efficient. Current process flows for elective CABG patients were then observed and documented for each surgeon. Each microsystem had a reasonable understanding of the processes in their area, but not how the entire process was interlocked. Figure 2 shows

#### Box 1: Creating a clinical application for a class I/IIa recommendation

##### ACC/AHA guideline 4.1.4. Reducing the risk of perioperative infection

The risk for deep sternal wound infection is reduced by aggressive control of perioperative hyperglycaemia by using a continuous intravenous insulin infusion.

Surgeon review of literature recommended that hyperglycaemic patients stay on insulin infusions until the third postoperative day, which for some patients would not be clinically feasible. Average length of stay for routine CABG patients was 3–4 days. Clinical practice warrants a period of observation in hospital after insulin infusions have been discontinued. If insulin infusions were maintained to the third postoperative day, patients might have the infusion stopped just prior to discharge without appropriate observation (or would require an additional hospital day).

Additionally, research supporting tight glycaemic control is derived from the ICU setting. However, the literature does not suggest when to commence insulin infusions for intraoperative hyperglycaemia. Most intensive care insulin protocols advocate that a patient's glucose be maintained at 80–110 mg/dl. Therefore, the surgeons decided to have a glucose of 110 mg/dl or greater as the trigger to begin an insulin infusion.

The formulated clinical application of recommendation 4.1.4. was developed as follows: For any CABG patient whose intraoperative glucose exceeds 110 mg/dl, a continuous intravenous insulin infusion will be started in the operating theatre and the infusion will continue until at least the morning of the second postoperative day.



component until the improvement teams felt that the correct process was in place (fig 3). Design reliability was incorporated into the process through extensive standardisation (table 2) and designed redundancy (box 3).

An in-depth evaluation of the EHR was carried out as a tool to assist in reliable care delivery. Clinical decision support, care flow maps and specially designed history and physical (H&P) templates provided additional support to the clinical staff (box 4).

After process component testing was completed, the team linked all components together to test the process from beginning to end. Multiple information sessions were held with all stakeholders in the months leading up to implementation.

### Phase 3: full implementation and data collection/feedback

In February 2006, *ProvenCare* went “live” roughly 6 months after programme design had begun. At “going live”, all participants knew that compliance with each of the process elements, both as a team and as individuals, would be followed and real-time feedback given. Because of the robust measurement strategy, any process defect was quickly identified and focused redesign was immediately initiated. This aggressive approach to identifying and correcting defects enabled the team to reach 100% reliability in 3 months.

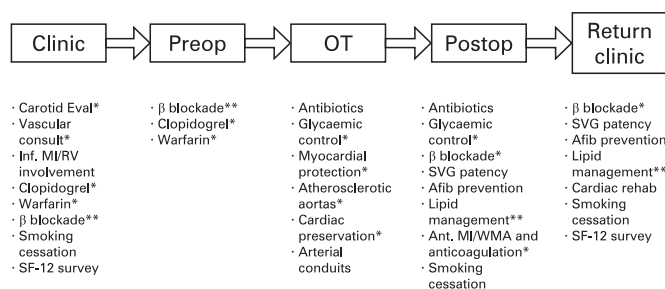
## Measurement

### Strategy

The measurement strategy was to abstract 100% of elective CABG surgical cases for each of the 40 care process elements. Elective CABG patients are those whose operations are neither urgent nor emergent cardiac cases and fall under diagnosis-related groups (DRG) no. 109. A standardised abstraction tool that graphically depicts the sequential delivery of care and highlights defects was developed (see fig 1 above). The clinical improvement specialist was notified as each new elective CABG patient entered the process and abstracted data in parallel with the care provided. Any variation or “failure” was fed back to the responsible care provider and the improvement team on the same day it occurred.

Other patient safety measures beyond the 40 cardiac care process elements, such as national patient safety goals and the IHI 100 000 lives campaign (eg, patient identification, operative time-out, central line insertion bundle, etc.) were compiled as part of larger system initiatives for each CABG patient.

Clinical outcome data was abstracted from the medical record by nurse specialists and physician assistants using the STS



**Figure 2** Elective coronary artery bypass graft *ProvenCare* high-level process flow. \*Practice variation; \*\*non-existent previous practice. Afib, atrial fibrillation; Ant, anterior; Eval, evaluation; Inf, inferior; MI, myocardial infarction; OT, operating theatre; RV, right ventricle; SF, Short Form; SVG, saphenous vein graft; WMA, wall motion abnormality.

## Box 2: Patient activation

It is our belief that active involvement of patients and families is essential to quality care. This is expressed in national patient safety goal no. 13, which encourages the involvement of patients in their care.<sup>5</sup> Also, being an engaged and active participant in one's own care is linked to better health outcomes.<sup>9</sup> Institutional values, solid evidence and feedback from our CABG patient/family interviews led us to create a “patient compact” (online appendix A). This compact codifies the mutual commitment of the cardiac surgery team, the patient and their family to the redesigned best practice processes. In addition, patient education materials were revised and standardised so all patients, regardless of where they presented, were assured of identical comprehensive information on their disease and the surgical process.

Adult Cardiac Surgery Database Data Collection Form and entered into the STS database. They abstracted consecutive elective CABG patients for a 12-month period before and after the intervention. Three patients were excluded from the post-intervention data set because they underwent a concurrent cardiac procedure (transmyocardial revascularisation) in addition to elective CABG.

### Analytical methods

This study adopted the “all-or-none” measurement strategy for the care process elements. Nolan and Berwick<sup>11</sup> explain the “all-or-none” strategy as follows:

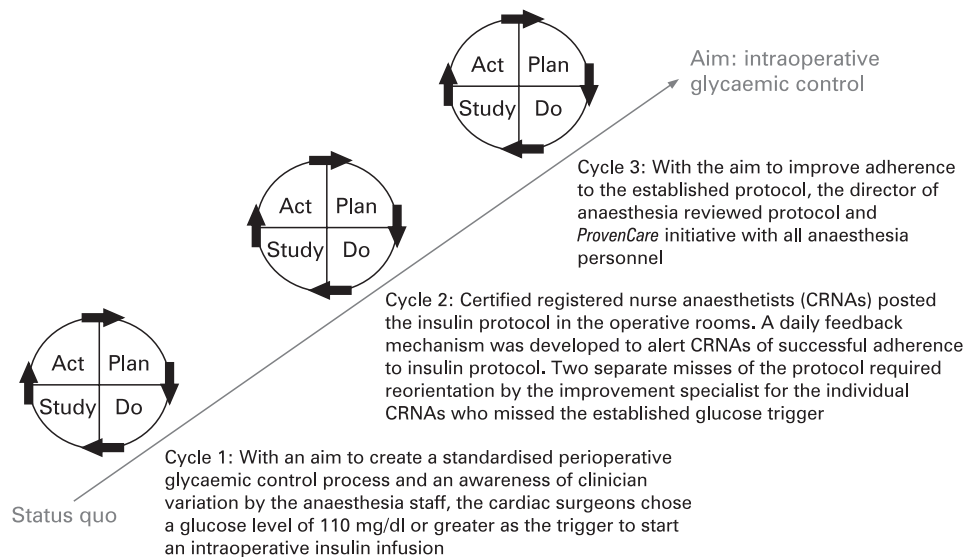
“A percentage is determined by applying an all-or-none rule at the patient level. For example, in pneumonia care the denominator could be the number of patients eligible to receive at least 1 of the 4 discrete elements of care and the numerator could be the number of patients who actually received all of the care for which the specific patient was eligible. No partial credit is given.”

This patient-centred focus best reflects what patients' want. The STS National Database outcome measure definitions were applied to outcome data.

**Table 2** Elective CABG design standardisation

Preoperative	Intraoperative	Postoperative
Patient history and physical examination queries	History and physical update queries	Postoperative order sets
Patient CABG education booklet	Perioperative antibiotic administration	Daily charting
Carotid Doppler evaluation	Perioperative glycaemic control	Discharge documentation
β-Blockade	Intra-aortic counterpulsation for low left ventricle ejection fraction	Postdischarge phone call queries
Cessation of antiplatelet therapy and anticoagulants	Operative note documentation	Postoperative clinic queries
	Management of significant atherosclerosis of the ascending aorta	Postoperative management of atrial fibrillation and anticoagulation
		Postoperative anticoagulation for recent anterior wall myocardial infarction
		Postoperative medical management
		β-Blockade
		Lipid management

Figure 3 Insulin ramp.



In three of the four quadrants (biological status, costs, patient satisfaction) of the Clinical Value Compass (CVC)<sup>12</sup> we had pre-intervention measures. We undertook specific actions to measure patient functional status, the fourth quadrant of the CVC, pre- and post-CABG using the short form (SF)-12 survey. Testing is currently underway to determine optimal timing for administering the post-CABG functional status survey. When completed, we will have an ongoing set of balanced measures.

## RESULTS

We followed 117 elective CABG patients treated within the Geisinger system from 2 February 2006 to 2 February 2007. Non-elective CABG patients (n=290) who did not undergo systematic application of the *ProvenCare* processes of care were not included in the outcome analysis. Nevertheless, these patients followed the same applicable care path and benefited from the process redesign.

The cohort of *ProvenCare* patients was compared with the 137 elective CABG patients (operated on in 2005) whose care was provided before the programme's initiation. The preoperative and operative characteristics used in the STS outcome predicting algorithms were similar in both cohorts except that left main coronary stenosis greater than 50% occurred more frequently in the *ProvenCare* Group (23% vs 12%, respectively), in keeping with the trend toward expanded use of percutaneous catheter intervention in patients with lesser degrees of coronary artery disease (table 3).

### Process measures

In the first month of the trial, 59% of patients had all *ProvenCare* care elements met. Compliance continued to increase to month 4, when 100% of elective CABG patients received all recommended care elements. There was a slight variance in months 5–7, but 100% of the recommendations were successfully delivered, beginning in month 8, for the next 5 months reported here (fig 4).

### Clinical outcome measures

Comparison of clinical outcomes between the two groups shows that most adverse events occurred less often in the post-intervention *ProvenCare* group although the difference was significant only for the likelihood of being discharged to home

(table 4). Although median postoperative length of stay was the same at 4 days for both groups, average total length of stay fell 16% from 6.3 days to 5.3 days for the *ProvenCare* Group and was reflected in a 5% reduction in hospital charges.

## DISCUSSION

### Summary

Redesigning the acute episodic surgical process to reliably deliver multiple EBM practices across the continuum of care results in improved health outcome trends for elective CABG patients. In addition, implementation of the *ProvenCare* model in one practice area (elective CABG) has resulted in the spread of EBM best practice into other cardiac surgical interventions (eg, urgent/emergent CABG, cardiac valve replacement). Anecdotally, in follow-up discussions with cardiac unit staff and the cardiac surgery physician assistants, better patient outcomes and decreased physician practice variation appeared to result in greater staff satisfaction.

### Context

Guided by John Ruskin's words, our work began "with the intent to make a superior thing." To our knowledge, this is the

### Box 3: Example of elective CABG process design redundancy

**Best practice:** If a patient is taking clopidogrel and/or warfarin preoperatively, unless contraindicated, we will have the patient stop those medications at least 5 days before surgery.

#### Design redundancy:

- ▶ Cardiac surgery clinic—patient instructed to stop clopidogrel/warfarin by clinician.
- ▶ EHR—if a patient is on these medications, an automatic patient reminder note generated as the electronic encounter is closed.
- ▶ Clinic check-out—patient handed reminder note to stop clopidogrel/warfarin.
- ▶ Surgical day—Standardised history and physical examination update includes query to determine if patient discontinued clopidogrel/warfarin. If patient did not stop medication, the surgeon is notified and surgery may be postponed.

## Box 4: Innovative use of EHR in delivery of reliable care

Prior to the implementation of this initiative, the documentation of the preoperative history and physical examination, performed in the clinic setting in the traditional manner, did not interface with the rest of the EHR. If a clinician identified a patient need for medications or laboratory tests, the clinician would have to close the H&P document and go into a separate order entry field. Evidence has shown that interruptions in the normal workflow can contribute to preventable medical error.<sup>10</sup>

To reduce this opportunity for error, we developed a document flow sheet that is contained within the EHR. The flow sheet includes a series of questions that facilitate compliance with specific recommendations. When the clinician answers a particular question within the flow sheet, an automatic order appears within the EHR order entry area. Examples of this process are:

**Question:** Does the patient have a history of peripheral vascular disease, stroke, transient ischaemic attack, or have a carotid bruit on physical examination?

**Action:** If "yes", a carotid duplex is automatically ordered within the EHR.

**Question:** Is the patient on a  $\beta$ -blocker?

**Action:** If "NO", a selection of different  $\beta$ -blockers automatically appears in the order area of the EHR. After choosing one of the available  $\beta$ -blockers, the physician cannot close the encounter without electronically signing the order. A computer-generated prescription is then printed and given to the patient.

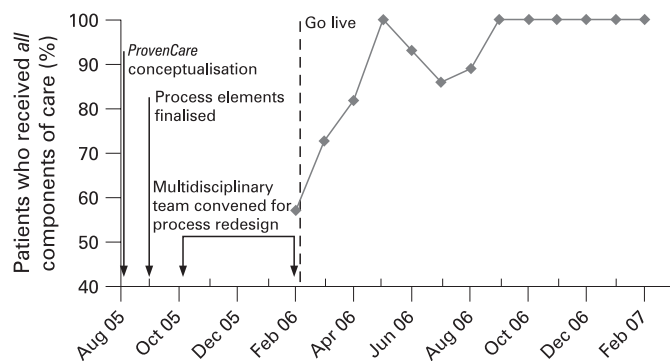
By having orders for studies automatically appear in the EHR, and a designed forcing function in the prescription process, we do not rely on the clinician's memory to complete these care steps, thereby improving the reliability of this component of *ProvenCare*.

**Table 3** Comparison of the conventional care and the *ProvenCare* groups—preoperative and operative characteristics<sup>13</sup>

Demographics	Conventional care	<i>ProvenCare</i>	p Value	Test type
	(2005) n = 137	(2006) n = 117		
	n (%) or mean (SD)	n (%) or mean (SD)		
Age (mean in years)	66 (10)	66 (11)	0.89	Equal t test
Men	100 (73.0%)	92 (76.8%)	0.30	$\chi^2$
White race	136 (99.3%)	115 (98.3%)	0.60	Fisher exact
Weight (mean in kg)	89 (22)	89 (20)	0.99	Equal t test
Height (mean in cm)	171 (11)	172 (10)	0.36	Equal t test
Body surface area (mean in m <sup>2</sup> )	2.05 (0.29)	2.06 (0.26)	0.80	Equal t test
Body mass index	30.4 (6.2)	30.1 (5.7)	0.60	Equal t test
Risk factors				
Diabetes	48 (35.0%)	44 (37.6%)	0.63	$\chi^2$
Hypertension	106 (77.4%)	87 (74.4%)	0.58	$\chi^2$
Renal failure	8 (5.8%)	7 (6.0%)	1.00	Fisher exact
Dialysis	4 (2.9%)	4 (3.4%)	1.00	Fisher exact
Hypercholesterolaemia	111 (81.0%)	90 (76.9%)	0.42	$\chi^2$
Immunosuppressive therapy	0 (0.0%)	0 (0.0%)	NA	
Cerebrovascular disease	15 (10.9%)	11 (9.4%)	0.84	Fisher exact
Peripheral vascular disease	19 (13.9%)	17 (14.5%)	1.00	Fisher exact
Smoker	81 (59.1%)	64 (54.7%)	0.48	$\chi^2$
Current smoker	23 (16.8%)	23 (19.7%)	0.55	$\chi^2$
Preoperative creatinine (median in mg%)	1.00	1.00	0.54	Wilcoxon
Stroke	10 (7.3%)	11 (9.4%)	0.65	Fisher exact
Previous cardiovascular interventions				
Prior coronary artery bypass graft surgery	4 (2.9%)	5 (4.3%)	0.74	Fisher exact
Preoperative cardiac status				
Myocardial infarction	37 (27.0%)	29 (24.8%)	0.69	$\chi^2$
Congestive heart failure	8 (5.8%)	4 (3.4%)	0.55	Fisher exact
NYHA class:				
I	10 (7.4%)	8 (6.8%)	0.89	$\chi^2$
II	60 (43.8%)	49 (41.9%)		
III	66 (48.2%)	58 (49.6%)		
IV	1 (0.7%)	2 (1.7%)		
Arrhythmia	12 (8.8%)	6 (5.1%)	0.33	Fisher exact
Haemodynamics and catheterisation				
Left main disease $\geq$ 50%	17 (12.4%)	27 (23.1%)	0.031	Fisher exact
Ejection fraction (mean)	52.3 (13.1)	54.6 (10.6)	0.12	Equal t test
Mitral insufficiency	24 (17.5%)	13 (11.1%)	0.16	Fisher exact
Number of diseased vessels = 3	106 (77.4%)	88 (75.2%)	0.77	Fisher exact
Aortic stenosis	2 (1.5%)	4 (3.4%)	0.42	Fisher exact
Operative				
Intra-aortic balloon pump	4 (2.9%)	2 (1.7%)	0.69	Fisher exact

NYHA, New York Heart Association.

## Original research



**Figure 4** ProvenCare coronary artery bypass graft surgery reliability.

first study in which planned process redesign has linked multiple Class I and IIa evidence-based medicine recommendations within an acute surgical episode to an explicit goal of reliably delivering these multiple recommendations 100% of the time. Individual studies have shown the efficacy of single interventions with subsequent patient outcomes, however, none explored the effects of multiple, linked interventions. Arguably, it is difficult to determine which intervention may have the most pronounced effect but, from the patient's perspective, all are necessary to ensure the optimal result.

### Interpretation

Nelson has indicated that commitment to change by macro-system and microsystem leadership is essential for successful process redesign (Nelson EC, personal communication, IHI National Forum, 2007) ProvenCare CABG was successful, in part, due to the unwavering support from system executive leaders. Leadership has been engaged from the inception of the idea through the allocation of resources needed to successfully

### Box 5: Example of data feedback in ProvenCare CABG

**Best practice:** To reduce the incidence of surgical site infection, patients will be placed on intravenous insulin infusions in the operating theatre once glucose readings exceed 110 mg/dl.

**Failure mitigation:** A patient's intra-operative glucose registered 113 mg/dl but the certified registered nurse anaesthetist (CRNA) did not initiate intravenous insulin. The CRNA commented: "It was only 113 mg/dl, so I decided to 'wait and see'." At the next operative check the patient's glucose had increased to 135 mg/dl, whereupon insulin was started. The clinical improvement specialist contacted the CNRA the next day to review the case and demonstrated that, in similar cases at Geisinger, once a patient's blood glucose exceeded 110 mg/dl the next glucose check will likely be higher. This quick feedback reinforced the agreed-on trigger point for initiation of intravenous insulin.

execute the initiative. At the frontline, the microsystem leader effectively helped change the previous highly autonomous practice into a consensus-driven practice.

The overarching quality education programme at Geisinger uses clinical microsystem fundamentals as a foundation of improvement work. This broad education programme strengthened the ability of our frontline caregivers to work through the implementation of this new model of care. "Improve microsystems, and we improve everything. Microsystems are where we meet not just the patients we serve but each other as well".<sup>14</sup>

Physician involvement in the process of evaluating and creating clinical application of class I and IIa recommendations was important to this initiative. Consensus about evidence is critical for the process redesign to begin. At the same time, the frontline caregiver is also critical to successful implementation

**Table 4** Comparison of conventional care group with ProvenCare: outcomes

	Conventional care (2005)	ProvenCare (2006)	p Value	Test type
	n = 137	n = 117		
	n (%)	n (%)		
Blood products used	32 (23.4)	19 (16.2)	0.17	$\chi^2$
Reintubated during hospital stay	4 (2.9)	1 (0.9)	0.38	Fisher exact
Total ventilation hours (median)	8	7.5	0.64	Wilcoxon
Operative complication	8 (5.8)	5 (4.3)	0.78	Fisher exact
Reoperation for bleeding	5 (3.6)	3 (2.6)	0.73	Fisher exact
Reoperation for other cardiac problem	1 (0.7)	1 (0.9)	1.00	Fisher exact
Reoperation for other non-cardiac problem	1 (0.7)	1 (0.9)	1.00	Fisher exact
Perioperative myocardial infarction	1 (0.7)	1 (0.9)	1.00	Fisher exact
Infection: sternum—deep	1 (0.7)	1 (0.9)	1.00	Fisher exact
Neurologic complication	2 (1.5)	1 (0.9)	1.00	Fisher exact
Pulmonary complication	10 (7.3)	3 (2.6)	0.15	Fisher exact
Prolonged ventilation	8 (5.8)	3 (2.6)	0.23	Fisher exact
Pneumonia	1 (0.7)	0 (0.0)	1.00	Fisher exact
Pulmonary embolism	1 (0.7)	0 (0.0)	1.00	Fisher exact
Renal failure	0 (0.0)	1 (0.9)	0.46	Fisher exact
Atrial fibrillation	31 (22.6)	30 (25.6)	0.58	$\chi^2$
Any complication (by STS database definition)	53 (39.0)	41 (35.0)	0.55	$\chi^2$
Postoperative length of atay (median)	4	4	0.25	Wilcoxon
Readmission to intensive care unit	4 (2.9)	1 (0.9)	0.38	Fisher exact
Operative mortality	2 (1.5)	0 (0.0)	0.50	Fisher exact
Discharge location = home	111 (81.0)	106 (90.6)	0.03	Fisher exact
Readmit <30 days from procedure	9 (6.6)	7 (6.0)	0.99	Fisher exact

STS, Society for Thoracic Surgery.

of this complex process. Involving a multidisciplinary micro-system team in the redesign expedites the redesign process, ensures that changes are incorporated into the normal workflow, and creates a sense of ownership. Furthermore, designing a process that “does the right thing” for every patient resonates with every healthcare professional. Reliability functions (standardisation, reminders, built-in redundancies, forcing functions, etc.) can be incorporated into the care path and EHR and are effective in helping staff meet care goals. Once all recommendations are linked within the continuum of care, “real time” feedback, transparent data sets and immediate focused redesign to mitigate failure is necessary in reaching  $10^{-3}$  reliability in elective CABG process measures (box 5).

## LIMITATIONS

The choice of the elective CABG procedure was both a strength and limitation of this initiative. There are a relatively limited number of microsystems that are linked across the continuum of care for the CABG patient, thereby decreasing the complexity of handover communications. Fewer handovers provide fewer opportunities for communication failure. Replicating this initiative with similar success may be more difficult in surgical interventions that require more linked microsystems in coordination of care. Our own tests in other surgical areas (eg, elective total hip replacement) indicate that, for some interventions, more robust communication and feedback tools are needed to achieve reliability. Another potential limitation of the generalisability of our initiative is our closed staff structure. All cardiac surgeons are employed members of the same hospital service line and answerable to the department chairperson. Compensation is tied to individual physician performance and compliance. Replicating our initiative might prove more difficult in an open-staffed model where individual physician autonomy is greater. Because of the rural setting of the Geisinger Health System, the study was limited by a relatively small sample size and was underpowered to detect more statistically significant changes. Continued data abstraction will augment our sample size and a second phase of analysis will be pursued. Finally, since CABG surgery is often performed urgently, elective CABG surgery is not a high-volume surgical intervention at Geisinger. The current process has not been subjected to high patient volumes and, therefore, might not have the appropriate design components to handle such.

## CONCLUSIONS

*ProvenCare* methodology appears to be applicable to episodic surgical intervention. Continued data abstraction over time will validate the robustness of the redesign. Although this article reviews this model only for elective CABG, we have actively applied it to other surgical interventions (elective total hip replacement, cataract surgery and percutaneous coronary intervention).

**Acknowledgements:** The authors thank the surgeons, physician assistants, nursing and anaesthesia staff of Geisinger’s Cardiac Surgery Service. Their hard work and commitment to their patients’ well-being has been instrumental in establishing *ProvenCare*. Special thanks are extended to Craig Wood for providing statistical support and to Melinda Reed for managing the STS database.

**Competing interests:** None.

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## APPENDIX A

## Patient compact

## My role in proven heart care

The Geisinger heart surgery team has your health and safety as its chief concern. That is why we established the *ProvenCare* Heart Program. The *ProvenCare* Heart Program includes all of the care steps necessary to ensure the highest quality care before, during and after your heart operation. Your *active* participation is one of the most important parts of the Geisinger *ProvenCare* Heart Program. Medical research has shown that the more involved you are in your own care—and the stronger the partnership between you and your caregivers—the better your results will be. Even though the Geisinger heart surgery team *always* strives to provide all of the elements of the *ProvenCare* Heart Program, you will get the best result when you, your family and your Geisinger heart surgery team are all *active* partners in your care.

## COMMITMENT TO COMMUNICATE AS A TEAM

- ▶ I will alert my heart surgery team when I don't understand something, when anything worries me, or if anything unexpected occurs, knowing that my heart surgery team will work with me until I am satisfied.
- ▶ I will discuss all of my current medicines, non-prescription products, vitamins or herbs as well as all of my current and past medical problems, recognizing how important this information is in guiding my care and making me safer.

## COMMITMENT TO INVOLVE MY FAMILY AND LOVED ONES

- ▶ I will have a trusted family member or loved-one present with me during my hospitalization and clinic visits—to help support me during my care.
- ▶ I will work with my heart surgery team to develop a sensible plan for my transition from the hospital back to my home.

## COMMITMENT TO COMPLETE IMPORTANT CARE STEPS

- ▶ I will alert my heart surgery team before I stop or start any of my medications so that we can discuss how any change might impact my care.
- ▶ I will work with my heart surgery team to develop a sensible schedule for my after-surgery care, follow-up visits and rehabilitation.

## COMMITMENT TO IMPROVED HEALTH AND PREVENTION

- ▶ I will complete a cardiac rehabilitation program, understanding that it will give me a better, quicker and more lasting recovery.
- ▶ I will work with my heart surgery team to stop my use of any tobacco products—forever.
- ▶ I will discuss with my heart surgery team the important role that life-long nutrition, weight management, exercise and medications play in keeping my heart healthy.

I realize that my decisions and my behavior have a significant positive impact on my long-term health. Because I want to become and stay healthy, I fully accept my role as a partner in the *ProvenCare* Heart Program.

Sincerely,

[INSERT NAME]

Date

[INSERT DATE]