Postoperative laboratory and imaging investigations in intensive care units following coronary artery bypass grafting: A comparison of two Canadian hospitals

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OBJECTIVES: To compare the utilization and cost of common laboratory and imaging tests following admission to the intensive care unit (ICU) after coronary artery bypass surgery in two hospitals. The hospitals use different strategies to order tests postoperatively: one hospital uses a mandated protocol while the other does not.

DESIGN: Demographic and testing data were prospectively collected in both hospitals as part of an ongoing ICU management program. Thirteen commonly performed laboratory tests or imaging procedures were compared. Average costs for each test were calculated, and utilization and cost of testing were compared per admission and per day in ICU.

SETTING: Two tertiary care ICUs in different Canadian cities.

PATIENTS: Consecutive patients admitted to ICU following coronary artery bypass graft surgery over a two-year period.

MAIN RESULTS: There were 415 admissions to the Health Sciences Centre in Winnipeg, Manitoba and 504 to the Jewish General Hospital (JGH) in Montreal, Quebec. There were no demographic, length of stay or ICU mortality differences. A postoperative protocol for ordering investigations is used at JGH. Striking differences in test utilization were noted, with more investigations performed per admission and per unit day at JGH ($P<0.001$). The average cost of the investigations was greater at JGH ($160 more per admission; $75 more per intensive care day).

CONCLUSIONS: There are marked differences in the investigation pattern and costs for coronary artery bypass patients admitted to ICU in these hospitals. It is suggested that the benefits of frequent routine determinations of bloodwork, electrocardiograms and chest radiographs should be reevaluated in this patient population. *(Pour le résumé, voir page 380)*

Key Words: *Coronary artery bypass graft surgery, Cost containment, Intensive care, Laboratory testing*

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Analyses de laboratoire et épreuves d'imagerie post-opératoires dans les unités de soins intensifs après le pontage coronarien : comparaison entre deux hôpitaux canadiens

OBJECTIFS : Comparer l'utilisation et les coûts des épreuves de laboratoire et d'imagerie courantes après l'admission aux soins intensifs (S.I.) pour pontage coronarien dans deux hôpitaux. Les hôpitaux utilisent des stratégies différentes pour ce qui est de demander les tests post-opératoires. Un hôpital utilise un protocole mandaté, l'autre non.

MODÈLE : Les données démographiques et les résultats d'analyses ont été recueillis de façon prospective dans deux hôpitaux dans le cadre d'un programme de gestion des soins intensifs en cours. Treize épreuves de laboratoire ou d'imagerie couramment utilisées ont été comparées. Les coûts moyens de chaque test ont été calculés et l'utilisation et les coûts des tests ont été comparés par admission et par jour aux soins intensifs.

CONTEXTE : Deux établissements universitaires de soins tertiaires, dans deux villes canadiennes différentes.

PATIENTS : Patients consécutifs admis aux soins intensifs après un pontage coronarien au cours d'une période de deux ans.

PRINCIPAUX RÉSULTATS : Quatre cent quinze patients ont été admis au Health Sciences Centre (HSC) de Winnipeg, au Manitoba et 504 à l'Hôpital Général Juif (HGJ) de Montréal, au Québec. On n'a noté aucune différence quant aux caractéristiques démographiques, à la durée du séjour ou à la mortalité durant le séjour aux S.I. L'HGJ a recours à un protocole post-opératoire pour demander les examens. Des différences frappantes d'utilisation des tests ont été notées, un plus grand nombre d'épreuves étant effectuées par admission et par unité à l'HGJ ($P < 0,001$). Le coût moyen de ces épreuves a été plus grand à l'HGJ (160 $ de plus par admission, 75 $ de plus par jour d'hospitalisation aux soins intensifs).

CONCLUSIONS : On note des différences marquées quant au mode d'utilisation des épreuves et aux coûts d'hospitalisation des patients aux soins intensifs pour pontage coronarien dans ces hôpitaux. On suggère une réévaluation des avantages des analyses sanguines, des électrocardiogrammes et des radiographies pulmonaires effectuées fréquemment de routine chez cette population de patients.

Coronary artery bypass graft (CABG) surgery is an expensive procedure usually requiring intensive care unit (ICU) admission. There have been initiatives to improve efficiency and cost effectiveness of care in CABG patients. These include minimizing preoperative and postoperative hospital admissions (1,2); early extubation to reduce ICU stay (3,4); and 'fast tracking' to bypass ICU admission (5,6). Costs also increase when complications occur after CABG surgery (7).

Most studies have concentrated on early extubation with rapid transfer from ICU to reduce costs. This is an appropriate strategy; however, at some point average ICU stays may not be subject to further reductions. A complementary strategy is to reduce unnecessary tests and procedures in ICU to reduce further the expense of ICU admission. We have previously shown that sustained reductions in testing can be achieved and maintained in a mixed ICU population by using an information-based management approach (8).

Patients admitted to ICU after CABG surgery usually undergo many laboratory studies because routine protocols may be used to order investigations. Recently the Jewish General Hospital (JGH) in Montreal, Quebec started an information-based management approach in their ICU. This hospital uses a protocol for postoperative testing of CABG patients. We hypothesized that there would be differences in test utilization and costs between JGH and the Health Sciences Centre (HSC) in Winnipeg, Manitoba for CABG patients related to the latter's mature information-based management program and its lack of a mandated protocol for testing. As a secondary hypothesis we speculated that comparisons between institutions might suggest areas to target for cost reduction in both centres.

PATIENTS AND METHODS

This study was conducted in two Canadian tertiary care teaching hospitals. The study population comprised consecutive ICU admissions in these hospitals following CABG between March 1, 1994 and February 29, 1996. The HSC has separate 10-bed medical and surgical ICUs. JGH has a 12-bed combined medical/surgical ICU. Both hospitals use a computerized database (Critical Care Manager 3.1, TMS) to facilitate ICU management. The Winnipeg program has been operational since July 1988, while Montreal's has been in operation since February 1994. Both units are multidisciplinary ICUs with attending ICU physicians directing a team of house staff who rotate through the units. The data collection process was approved by the institutional review board at the University of Manitoba. Informed patient consent was not required for this data collection process.

Both hospitals prospectively collect identical demographic, diagnostic, length of stay, admission Acute Physiology and Chronic Health Evaluation II (APACHE II) scores (9) and daily Therapeutic Intervention Scoring System (TISS) (10) scores on all ICU admissions. Frequency of selected laboratory tests, imaging procedures and pharmaceutical administration are collected on a per admission basis during the ICU stay. A cost list for these items was generated by independent hospital finance committees at each location, in cooperation with laboratory departments. Calculations were based on actual labour, materials, supplies and equipment costs incurred by the hospital (8). Capital equipment costs were not included.

Each hospital collects different tests and has different costs recorded. Laboratory or imaging procedures performed in over 90% of the population at either hospital, or items that accounted for significant costs (over $10,000) at either location during the two-year study period were compared. The specific laboratory and imaging items were complete blood count (CBC); sodium, potassium, chloride, carbon dioxide content, urea, creatinine, glucose (SMA7); prothrombin/partial thromboplastin time (PT/PTT); magnesium content; calcium content; chest radiograph (CXR); electrocardiogram (ECG); arterial blood gas (ABG); creatine kinase (CK); MB isoenzyme of CK (CK-MB); aspartate

transaminase (AST); alanine transaminase (ALT); and phosphate. For cost comparisons the average unit cost of each test was calculated. Testing patterns were examined both per admission and per ICU day.

In Winnipeg all blood tests except ABG are directly downloaded into the ICU database from the hospital information system. CXRs, ECGs and blood gases are manually counted and entered. In Montreal all items are manually counted and entered.

The ICU in Winnipeg does not have an extensive protocol or standing orders for investigation of CABG patients after ICU admission. The cardiac surgery program has been in operation for many years at this hospital. An ECG, CXR, electrolytes, CBC, PT/PTT, ABG and glucose are determined on arrival and then additional tests are ordered as indicated. Calcium, magnesium, CK, AST, ALT and CK-MB are only done with a specific order.

Cardiac surgery is a relatively new program at JGH in Montreal. When the cardiac program started, a standard protocol was developed for postoperative ICU investigations. The protocol was developed to improve patient safety and staff comfort during the introduction of cardiac surgery. On ICU admission CXR, ECG, SMA7, CK, CK-MB, PT/PTT, CBC and ABG tests are done. At 15:00 or 16:00 on the operative day a CBC and SMA7 are ordered. At 21:00 on the operative day CXR, CBC and SMA7 are done. At 05:00 on the first postoperative day, and each morning on postoperative days 2 and 3, the following tests are ordered: CXR, ECG, CBC, CK, CK-MB and SMA7.

Statistical analysis was performed using Student's t and χ^2 tests as appropriate when normal distributions were encountered. Mann-Whitney U tests were used when non-normal distributions were found. A significance level of 0.05 was used for comparisons. All cost data are given in 1996 Canadian dollars.

TABLE 1
Demographic and intensive care unit (ICU) mortality data for coronary artery bypass patients at the Health Sciences Centre (HSC), Winnipeg and the Jewish General Hospital (JGH), Montreal

Parameter	HSC (n=415)	JGH (n=504)
Females (%)	101 (24.3)	125 (24.8)
ICU mortality (%)	15 (4)	22 (4)
Mean length of stay (days)	2.0±2.9	2.2±3.0
Length of stay range (days)	0.15-23.6	0.01-36.7
Mean APACHE II score	13.7±5.3	13.7±5.9
APACHE II range	3-41	3-47
Mean age (years)	64.6±11.1	64.8±10.2
Age range (years)	34-86	36-89
Mean TISS score*	49.1±6.8	49.6±6.0
TISS range	27-80	26-71

*Data are mean ± SD. P values for mortality and sex ratio were determined from χ^2 test and all others from Student's t test; all differences were nonsignificant. *61 missing Therapeutic Intervention Scoring System (TISS) scores at HSC. APACHE II Acute Physiology and Chronic Health Evaluation II*

RESULTS

There were 415 admissions to ICU in Winnipeg following CABG and 504 post-CABG admissions in Montreal. Demographic and survival data are shown in Table 1. The populations were similar with no significant differences noted in age, mean ICU length of stay, mean APACHE II score, mean admission TISS score or ICU mortality. Admission TISS scores were missing for 61 HSC patients. The ICU length of stay was skewed at both hospitals, with 80% of admissions at HSC and 75% of JGH admissions lasting less than two days. Median length of stay was similar (1.0 day at HSC and 1.1 days at JGH).

Major differences were noted in testing patterns between the hospitals. More tests per admission were done at JGH than at HSC. Table 2 shows the total number of tests during

TABLE 2
Total number of tests, and tests per admission and per day in the intensive care unit (ICU) at the Health Sciences Centre (HSC), Winnipeg and the Jewish General Hospital (JGH), Montreal following coronary artery bypass surgery

	Total tests		Tests/admission			Tests/ICU day		
Investigation	HSC	JGH	HSC	JGH	P	HSC	JGH	P
CBC	1491	2502	3.6±4.0	5.0±4.6	<0.001	1.8±0.9	2.4±1.1	<0.001
PT/PTT	1443	2517	3.5±4.1	5.0±5.0	<0.001	1.8±1.0	2.4±1.1	<0.001
SMA7	2218	3191	5.3±2.4	6.3±5.7	<0.001	2.4±1.2	3.1±1.4	<0.001
Calcium	851	1025	2.1±3.2	2.0±2.9	0.24	1.0±0.9	1.0±0.8	0.71
Phosphate	829	980	2.0±3.2	1.9±3.1	0.99	1.0±0.9	0.9±0.8	0.34
Magnesium	965	1496	2.3±3.5	3.0±3.3	<0.001	1.1±0.9	1.4±0.8	<0.001
ALT	64	1382	0.2±0.7	2.7±3.0	<0.001	0.0±0.2	1.3±0.8	<0.001
AST	72	1929	0.2±0.6	3.8±3.4	<0.001	0.1±0.3	1.9±0.9	<0.001
CK	317	2228	0.8±1.7	4.4±3.7	<0.001	0.2±0.5	2.2±1.0	<0.001
CK-MB	175	1730	0.4±1.2	3.4±2.6	<0.001	0.2±0.5	1.8±0.9	<0.001
ECG	868	2622	2.1±1.6	5.2±4.8	<0.001	1.3±0.7	2.5±1.3	<0.001
CXR	1175	2243	2.8±2.9	4.5±4.1	<0.001	1.5±0.8	2.2±0.9	<0.001
ABG	6112	6493	14.7±17.6	12.9±12.2	0.22	7.1±4.0	6.3±2.8	0.003

Data are mean ± SD. P values were determined by Mann Whitney U test. ABG Arterial blood gases; ALT Alanine transaminase; AST Aspartate transaminase; CBC Complete blood count; CK-MB Creatine kinase MB isoenzyme; CK Creatine kinase; CXR Chest radiograph; ECG Electrocardiogram; PT/PTT Prothrombin/partial thromboplastin time; SMA7 sodium, potassium, chloride, carbon dioxide content, urea, creatinine, glucose

TABLE 3
Costs per admission and per day in the intensive care unit (ICU) for investigations at the Health Sciences Centre (HSC), Winnipeg and the Jewish General Hospital (JGH), Montreal following coronary artery bypass surgery

Investigation	Average test cost ($)	Cost per admission ($)		Cost per ICU day ($)	
		HSC	JGH	HSC	JGH
CBC	4.80	17.23	23.80	8.63	11.62
PT/PTT	6.12	21.28	30.54	11.05	14.70
SMA7	8.43	45.03	53.34	20.56	26.42
Calcium	3.14	6.44	6.39	3.21	3.00
Phosphate	2.11	4.21	4.10	2.06	1.89
Magnesium	4.52	10.50	13.40	5.18	6.35
ALT	2.11	0.33	5.79	0.09	2.76
AST	1.97	0.34	7.54	0.13	3.69
CK	4.52	3.45	19.96	0.74	9.84
CK-MB	8.41	3.54	28.85	1.39	14.85
ECG	14.85	31.06	77.26	18.59	36.74
CXR	23.88	67.60	106.25	35.09	52.14
ABG	3.49	51.27	44.96	24.68	22.16
Total cost		262.28	422.18	131.40	206.16

ABG Arterial blood gases; ALT Alanine transaminase; AST Aspartate transaminase; CBC Complete blood count; CK-MB Creatine kinase MB isoenzyme; CPK Creatine kinase; CXR Chest radiograph; ECG Electrocardiogram; PT/PTT Prothrombin/partial thromboplastin time; SMA7 Sodium, potassium, chloride, carbon dioxide content, urea, creatinine, glucose

the study period, mean tests per admission and mean tests per ICU day at each location. In only three of the 13 investigations were more tests per admission done at HSC than at JGH. None of these were statistically significant. Large differences in the use of ALT, AST, CK, CK-MB, ECG and CXR were noted between the two hospitals with significantly more use of these investigations at JGH ($P<0.001$).

Because tests per admission can be skewed by very long stays, tests were examined per ICU day. To standardize comparisons, individual lengths of stay were rounded up to the nearest whole day. Table 2 shows the testing data per ICU day for the two hospitals. HSC did more ABG per day than JGH ($P<0.003$), but calcium and phosphate frequency were not significantly different. For all other investigations the frequency per ICU day was greater at the JGH ($P<0.001$). The differences in frequency were greatest for AST/ALT, CK, CK-MB and ECG.

The cost implications of these differences in testing frequency are examined in Table 3. The costs shown for each test are the average of the costs at the two hospitals. Costs per admission and per ICU day were greater at JGH. The most impressive differences are in some of the expensive tests. The cost per day of ECG was almost double at JGH. Measurement of CK and CK-MB were 10 times more expensive at JGH than at HSC. Overall for these 13 investigations $75 more was spent per patient day in Montreal than in Winnipeg. This represents a potential savings of $81,975 over the two-year study period.

DISCUSSION

The major finding of this study was that many more investigations were done at JGH following ICU admission of a CABG patient. There were no relevant demographic or acuity differences between the two study populations to account for this. All patients were admitted after the same surgical procedure. Admissions to the two hospitals had identical mean and median ICU lengths of stay, and no difference in ICU mortality was found. There were important cost differences related to increased testing at JGH.

We elected to study ICU admissions following CABG surgery because we felt that this population would be well matched for preoperative and intraoperative variables between the two institutions. Estimates suggest that nearly 500,000 patients have cardiac surgical procedures annually in the United States, and these patients have usually been admitted to ICU (11). This has important cost implications if the findings of our study are indicative of what is happening in other North American centres. We found a difference of $160 per admission between the two hospitals we studied. Extrapolated broadly over 500,000 patients this could result in $80,000,000 in additional costs if all hospitals have investigation patterns similar to those of JGH.

Little is known about investigation patterns in ICU. There are data suggesting that too many tests are done in ICU patients. Civetta and Hudson-Civetta (12) identified this in 1985 and suggested 10 corrective measures. Our group demonstrated that testing can be reduced in a sustained manner without adversely affecting patient care by implementing an information-based management approach (8). We do not think that we were particularly inefficient or wasteful in our investigation pattern before this initiative, and doubt that our previous testing practices differ significantly from what is currently routine in many ICUs across North America. We suspect that many hospitals use postoperative CABG protocols similar to those of JGH and that investigation patterns similar to those of JGH are not uncommon. Recently we demonstrated marked differences in testing among ICUs within Winnipeg and found higher in-

vestigational costs for surgical admissions at another teaching hospital in our city (13). It appears that the current data extend this to ICUs in different cities and suggests that there are marked differences in testing practices among ICUs.

There have been initiatives to reduce preoperative testing that have been widely supported (14,15), and the utility of routine admission blood tests in trauma patients has been examined (16). Our findings suggest that attention should also be paid to reducing postoperative testing in selected populations. There has been one reported success in the field of craniofacial surgery (17). Marked differences in postoperative testing were achieved without adverse patient impact. Similar initiatives in CABG patients would have more potential benefit because of the large number of procedures involved.

A study examining the appropriateness of routine chest radiography after CABG concluded that ICU admission CXR should only be done in postoperative cardiac surgery patients if clinical and laboratory assessment suggest the possibility of pathology (18). Because CXR is a relatively expensive test, elimination of one or two radiographs per admission could have important cost implications. We are not aware of any studies addressing the appropriateness of laboratory testing after CABG surgery. We believe that our results indicate that JGH was performing too many CXRs, ECGs and enzymatic assays. There also appeared to be a general increase in all testing because measurement of CBC, SMA7 and PT/PTT were also significantly greater in Montreal. Much of this testing was driven by the use of a standardized protocol mandating frequent laboratory tests at JGH. The identical average ICU length of stay and mortality suggests that extra testing at JGH did not result in direct patient benefit. We cannot rule out benefit after ICU discharge related to identification of a perioperative myocardial event and modified postoperative management related to this; it seems unlikely, however, because perioperative myocardial infarction (MI) is relatively uncommon (3% incidence in a previous study at HSC) (19), and there are definite limitations in ECG and CK determinations for the diagnosis of MI post-CABG (20-22). There are also data indicating that patients with a postoperative MI but preserved ventricular function have long term outcomes similar to those without an MI (23-25).

Similar levels of testing were noted between the two hospitals for calcium, phosphate and blood gases. Blood gas findings are significant because they are performed more frequently than calcium or phosphate determinations. Increased use of blood gas determinations at HSC was a surprising finding because there are published algorithms in use at HSC to determine when ABG measurement is indicated (26). Given the changing anesthetic management of these patients it is probable that both hospitals were doing too many ABG determinations. Pulse oximeters are in use in both centres, and time on the ventilator seems to be decreasing. These factors should reduce the need to measure ABG. These findings suggest that ongoing monitoring and intervention is needed at both hospitals to reduce measurement of blood gases in this population. Overall, our results suggest that physicians should reconsider the usefulness of the tests they order after CABG surgery. Preset protocols that mandate frequent testing even when abnormalities are not expected may not be required for good patient outcomes. This finding might be specific to hospitals with 24 h in-house medical coverage and should be studied further before application outside of this setting. We have no evidence that the protocols at JGH allowed reductions in staffing or monitoring compared with HSC. Nursing ratios for these patients were similar at the two sites, and TISS scores indicate that nursing interventions and monitoring were the same.

The cost implications of this study deserve some emphasis. Laboratory testing in the ICU is only a small component of the cost of caring for CABG patients. The largest expense in ICU is labour costs for nursing. This has recently been studied by another Canadian group (3). Strategies resulting in decreased ICU length of stay, early extubation and reduction of patient:nurse ratio will result in the most significant savings. While reductions in laboratory testing will result in smaller savings they can be significant. We found that $75 more per day was spent each day a CABG patient was in ICU at JGH than at HSC. Considering the number of patients and patient days involved, significant cost savings for the institution could be achieved if testing at JGH were reduced. This could have greater economic impact if levels of testing comparable with what we observed in Montreal are common in other centres. If this is the case clear cost savings could be realized by rationalizing postoperative testing strategies. There are other reasons besides cost reduction to decrease unneeded testing. Robin (27) has described four types of harm that can occur because of unneeded testing: technical errors in laboratory results; interpretive errors resulting in incorrect decisions; injuries from invasive procedures as a result of interpretive errors; and information overload. We should be encouraged to decrease testing to avoid these problems as well as to reduce costs.

CONCLUSIONS

Marked differences were found in the investigation pattern and costs for CABG patients admitted to ICU postoperatively at two Canadian hospitals. The study suggests that monitoring testing frequency in ICU and comparing this with other institutions could be useful to identify potentially unneeded testing. We suggest that the benefits of frequent routine determinations of bloodwork, ECG and CXR should be reevaluated in CABG patients admitted to ICU.

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