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Clinical Investigations

Eliminating needless testing in intensive care—An information-based team management approach

DANIEL E. ROBERTS, MD, FRCP; DEAN D. BELL, MD, FRCP; TRISH OSTRYZNIUK, RN; KAREN DOBSON, RN; LUIS OPPENHEIMER, MD, FRCP; DOUGLAS MARTENS, BSc; NICHOLAS HONCHARIK, PharmD; HARVEY CRAMP, RT; ELFREIDE LOEWEN, RT; SHEILA BODNAR, RN; ANN GUENTHER, BN; LORRAINE PRONGER, RN; EDWARD ROBERTS, MSc; THOMAS A. McEWEN, MSc

Objective: **To determine if the application of an information-based management system in adult intensive care units (ICU) can produce sustained decreases in the use of laboratory resources and costs.**

Design: **Interventional study with prospective data collection on consecutive patients admitted during three time periods.**

Setting: **A 10-bed adult surgical ICU and an eight-bed adult medical ICU in a tertiary care hospital.**

Patients: **All patients admitted to an ICU during a 7-month baseline period (n = 647), a 1-yr intervention period (n = 1236), and a 2-yr follow-up period (n = 2349).**

Interventions: **Using a management database to track the use of 123 laboratory investigations during the baseline period, nine frequently ordered investigations (determination of blood gases, glucose, potassium, electrocardiogram, chest radiograph, sodium, chloride, complete blood count with differential, and serum osmolality) were targeted for reduction. Specific policies were developed by a multidisciplinary committee within the ICU to reduce the utilization of these laboratory, radiology, and cardiology tests. The policies were applied to all patients admitted during the 1-yr intervention period and during the 2-yr follow-up period.**

Measurements and Main Results: **A 25% reduction was observed in the frequency of all 123 monitored tests during the intervention period. The most dramatic reductions occurred in the nine targeted tests (range 19% to 46%) ($p < .001$). There were significant reductions in only 13 of the untargeted 114 investigations during this period. Potential annual cost savings were >$150,000 Canadian. No increases in ICU mortality rate, length of stay, or cost of medication were observed, and the reductions in the frequency of targeted tests were maintained during the 2-yr follow-up period.**

Conclusions: **Application of an information-based multidisciplinary management system in the ICU can produce marked and sustained reductions in unnecessary testing in a cost-effective manner. Although rationing of intensive care services may be necessary, reducing needless testing can be a safe and effective cost-containment strategy in the ICU.(Crit Care Med 1993; 21:1452–1458)**

Key Words: intensive care; severity of illness index; resource utilization; quality of health care; cost savings; cost control; laboratory investigations; patient management; critical illness

Providing intensive care is comparatively expensive and often futile. However, it is reasonable to expect that the demand for critical care services will continue to expand as new treatment modalities develop (1, 2).

To date, efforts to control the costs of intensive care, such as capping institutional budgets and limiting third party payments, have produced mixed results (2–5). A frequently discussed direct strategy centers around the rationing of critical care services. There are morally valid, noneconomic reasons for halting futile therapy; however, the denial of admission to an intensive care unit (ICU) or early withdrawal of therapy in groups of patients with poor anticipated outcomes is perceived to have potential cost containment benefits (6–11).

From the University of Manitoba, Health Sciences Centre, Winnipeg, MB, Canada.

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Implicit in the concept of rationing is the assumption that similar savings cannot be achieved by identifying and reducing waste. In other areas of the hospital, initiatives have been undertaken to reduce the frequency of discretionary or unnecessary diagnostic testing. However, most strategies for containing laboratory testing have not produced sustained effects (12, 13).

We hypothesized that a cost-effective, practical management approach could be employed in adult medical and surgical ICUs to reduce the frequency of diagnostic laboratory testing in a sustainable manner, and that this approach would result in cost savings. This project and its methodology were designed to improve the efficiency and quality of patient care.

MATERIALS AND METHODS

Setting. The Health Sciences Centre is a 1,000-bed university-affiliated, tertiary care, teaching hospital with a ten-bed surgical ICU and a separate eight-bed medical ICU. Both units have full-time medical directors and are staffed by trained intensivists who direct medical teams consisting of critical care fellows; residents from anesthesia, medicine, and surgery; and interns. The attending physicians control admissions and discharges, and patient care orders are written exclusively by the ICU staff. Off-hour coverage is provided by dedicated, inhouse resident physicians or their equivalent. Intensivists are paid by a sessional per diem, which precludes all fee for service payments for consultations or procedures. A patient/nurse ratio of 1:1 or 2:2 is maintained. Additional resources include a blood gas laboratory within close proximity that is staffed by respiratory therapists, a full-time dietitian, and a shared satellite pharmacy.

Study Design and Data Collection. The project was approved by the Institutional Review Board of the University of Manitoba, who felt patient consent was not required. The study was performed in two phases. Phase I consisted of a 7-month baseline period where population characteristics were recorded and patterns of resource utilization were identified and analyzed. A multidisciplinary committee was established to review baseline data, identify opportunities for improving efficiency, and to develop and implement appropriate interventions. The effects of several specific interventions were assessed during a 12-month period (phase II) immediately after phase I.

Phase I. The baseline study population consisted of all patients admitted to the ICU between July 11, 1988 and February 15, 1989. Demographic data that were collected included name, chart number, an assigned study number, date of birth, dates and times of admission and discharge, up to three admission and three discharge diagnoses, and ICU survival. These data were collected by a research nurse who also tabulated all elements required to calculate the worst Acute Physiology and Chronic Health Evaluation (APACHE II) score for the first 24 hrs after admission (14). A Therapeutic Intervention Scoring System (TISS) form was completed every 24 hrs for the first 5 days of the ICU stay at the end of each evening shift by the bedside nurse (15). The frequencies of 123 common laboratory procedures were logged for each patient by the research nurse. In addition, total numbers of blood gas measurements were tabulated for each study unit during both study periods, but were not entered separately for each patient. Cumulative dosages of 87 commonly used pharmaceuticals were calculated for each patient by staff pharmacists.

All data were entered into a computerized database, designed specifically for analysis and management of patient-based resource utilization (Critical Care Manager, TMS, Chelmsford, ON, Canada). Data processing was performed on an IBM-compatible computer. A laboratory cost list included in the database that was developed by an independent hospital finance committee, in cooperation with the individual laboratory departments. Calculations were based on actual labor, materials, supplies, and equipment costs incurred by the hospital.

Management Committee. During the last 2 months of phase I, a multidisciplinary management committee, consisting of intensivists, head nurses, pharmacists, respiratory therapists, and research associates was established. Members were assigned to review and analyze cumulative data and identify opportunities to improve the quality of care and/or efficiency of resource utilization. The committee initially concentrated on laboratory tests performed in >50% of patients. Standard, cumulative, computer-generated reports were provided to committee members at regular intervals. These reports included both volume and cost of laboratory testing and drug administration. Subgroup population search reports specified by diagnoses, ranges of demographic indices, and/or resource items (i.e., tests, drugs, interventions) were provided when requested. The committee initially generated and introduced five policies and algorithms to reduce unnecessary utilization of the tests specified below.

Interventions. No policies or guidelines describing appropriate indications for routine testing were previously in place for the following five tests:

a) Serum Osmolality. The high frequency of this determination that was observed during phase I was ascribed to the inclusion of this test in the routine electrolyte laboratory requisition form. Several of the

ICU ward clerks had been checking off this investigation each time electrolytes were ordered. The form was altered to exclude serum osmolality.

b) Complete Differential White Blood Cell Count. Frequent ordering of this test by physicians was observed during the baseline period, despite repeated, normal total white blood cell counts. A policy was established whereby physician orders for differential counts were ignored if machine-determined white blood cell counts were normal.

c) Serum Sodium, Potassium, and Glucose. Factors leading to frequent routine serum electrolyte and glucose ordering included the use of intravenous potassium and insulin infusions and the absence of written guidelines that described indications for routine testing. Interventions included introduction of bedside glucometers in the two adult ICUs. Unused devices were obtained from the clinical chemistry laboratory without the need for any new capital expenditure. Frequency of routine electrolyte determinations in patients who received potassium or insulin infusions was described by a written policy that was integrated with an existing sliding scale for potassium and insulin administration. The policy stated that the blood glucose concentration should be assessed every 2 hrs using a glucometer if insulin was infused at a rate >5 units/hr, and every 2 or 4 hrs, depending on the physician order, if the insulin infusion rate was <5 units/hr. Patients receiving potassium infusions had electrolytes measured every 12 hrs if the baseline circulating potassium concentration was between 3.5 and 4.0 mEq/L and the potassium infusion rate was ≤5 mEq/hr. If the infusion rate was 7.5 mEq/hr, electrolytes were measured every 6 hrs; if the rate was 10 mEq/hr, they were assessed every 4 hrs; and if the potassium infusion rate was >15 mEq/hr, electrolytes were assessed every 2 hrs. The policy called for the infusion rate and frequency of blood work to decrease as the serum potassium level increased toward the normal range. Patients with clinically important renal compromise were not managed with this protocol.

d) Chest Radiographs and Electrocardiograms. Phase I results demonstrated that chest radiographs and electrocardiograms (EKG) were performed without clear indications. Physicians were informed that these investigations were not needed on a daily basis and that requests for these tests should be based on clinical necessity. Fellows were instructed to routinely ask junior housestaff to justify ordering these tests. No written policies were introduced.

e) Blood Gases. Even in stable patients, multiple daily blood gases, including arterial and mixed venous samples, were sent routinely by bedside nurses. A detailed algorithm (16) was developed in cooperation with the Nursing and Respiratory Therapy departments.

These interventions were introduced between February 16, 1989 and May 1, 1989.

Phase II: As previously described, complete data were collected for all patients admitted to the study units between February 16, 1989 and February 15, 1990 to allow comparisons between the study populations and to determine the effect of the interventions on laboratory utilization. The average number of tests and the cost per admission were compared during both phases. Some have argued that the appropriate unit of analysis is tests or costs per physician (17). We did not feel this approach was practical in our units, as physicians rotated continually through the units and many decisions about testing were made by the ICU team during rounds. Assessing laboratory utilization per admission was thought to be more useful, given the difficulties of tracking the ordering behavior of individual physicians.

Statistics. Selected variables were exported from the database to Standard Code For Information Interchange (ASCII) files and subsequently imported to Lotus 1-2-3 (Lotus Development, Cambridge, MA) and NCSS (Dr. Jerry L. Hintze, Kaysville, UT) for detailed statistical analysis. Sex and survival data were compared using chi-square tests. Other variables (age, APACHE II score, TISS score, length of stay) were analyzed using Student's *t*-test. The Wilcoxon rank-sum test was used to compare blood gas data. Normally distributed data were compared by analysis of variance and modified two-tailed Student's *t*-test.

RESULTS

Complete information was collected for 647 consecutive admissions to the study units between July 11, 1988 and February 15, 1989 (phase I) and 1,236 consecutive admissions between February 16, 1989 and February 15, 1990 (phase II).

Population Characteristics. There were no differences between phase I and phase II study populations when comparing age, sex, and acuity of illness as assessed by APACHE II score and TISS score. ICU survivors were similar in the medical ICU and increased in the surgical ICU during phase II ($p < .05$) (Table 1). The ten most frequent diagnoses leading to admission for each unit are listed for both phases of the study (Tables 2 and 3) and are very similar. In each unit, these ten admitting diagnoses account for >50% of the admitted patients.

Testing Frequency. Laboratory testing frequencies before and after interventions for the 20 most frequently ordered laboratory investigations are

Table 1. Demographic characteristics of the patient population admitted to the medical (MICU) and surgical (SICU) intensive care units during the two study phases

	MICU Admissions		SICU Admissions	
Characteristic	Phase I	Phase II	Phase I	Phase II
Admission (number)	244	492	403	744
Sex (male/female)	148/96	282/210	259/144	502/242
Age (yr)	54.3 ± 20.0	55.4 ± 20.2	60.0 ± 17.7	59.3 ± 17.8
APACHE II score	22.9 ± 9.1	21.5 ± 10.3	18.1 ± 7.8	17.6 ± 7.7
Average ICU stay (days)	4.3 ± 6.5	4.1 ± 6.0	3.5 ± 6.0	3.1 ± 5.2
Average day 1 TISS score	32.8 ± 11.9	29.5 ± 12.4	41.8 ± 13.2	39.9 ± 12.7
ICU Survival (%)	80.7	77.4	87.3[b]	91.1

Phase I, 220 days; Phase II, 365 days; APACHE, Acute Physiology and Chronic Health Evaluation; TISS, Therapeutic Intervention Scoring System.

[a]Mean ± SD; [b]$p < .05$ by chi-square; all other comparisons were nonsignificant.

Table 2. Ten most frequent admission diagnoses in the medical ICU during study periods I (220 days) and II (365 days)

	No. of Admissions	
Diagnosis	Phase I (n = 244)	Phase II (n = 292)
Post arrest	33 (13.5)	71 (14.4)
Pneumonia	37 (15.2)	48 (9.8)
Septic shock	24 (9.8)	37 (7.5)
CHF	12 (4.9)	29 (5.9)
COPD	9 (3.7)	24 (4.9)
TCA overdose	5 (2.0)	15 (3.0)
Cardiogenic shock	5 (2.0)	14 (2.8)
Myocardial infarction	5 (2.0)	14 (2.8)
Multiple overdose	3 (1.2)	12 (2.4)
Status asthmaticus	4 (1.6)	11 (2.2)
Total	137 (56.1)	275 (55.9)

CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; TCA, tricyclic antidepressant. Numbers in parentheses are percentages.

compared in Table 4. Changes ranged from a 46% decrease in the frequency of serum osmolality testing to a 1% decrease in both serum magnesium and serum phosphate testing frequency. Reductions ranging from 19% to 46% were observed for all tests targeted by study interventions ($p < .001$). These nine items accounted for 57.7% of all tests recorded during phase I. Of the 11 separately identified, nontargeted investigations in Table 4, only two (serum calcium and serum creatine phosphokinase) decreased significantly ($p < .01$, $p < .02$). There were significant reductions in 11 of the

Table 3. Ten most frequent admission diagnoses in the SICU during study periods I (220 days) and II (365 days)

	No. of Admissions	
Diagnosis	Phase I (n = 403)	Phase II (n = 744)
CABG	84 (20.8)	146 (19.6)
Valve replacement	30 (7.4)	46 (6.2)
AAA	28 (6.9)	46 (6.2)
Exploratory laparatomy	15 (3.7)	33 (4.4)
Aortofemoral bypass	14 (3.5)	28 (3.8)
GI bleed	12 (3.0)	13 (1.7)
Other cardiac/vascular	11 (2.7)	21 (2.8)
Thoracotomy	9 (2.2)	24 (3.1)
Traumatic intracranial bleed	9 (2.2)	23 (3.1)
Subarachnoid hemorrhage	2 (0.5)	13 (1.7)
Total	214 (53.1)	393 (52.8)

CABG, coronary artery bypass grafting; AAA, abdominal aortic aneurysm repair; GI, gastrointestinal. Numbers in parentheses are percentages.

remaining 103 investigations; however, these tests accounted for only 3.4% of all tests performed in the Phase I population. Although combined unit results are presented in Table 4, it should be noted that similar reductions in testing frequency were observed in both units, despite differences in the demographic and diagnostic characteristics between units.

An overall reduction of 25% in tests per admission was observed following our interventions (Table 5). Most of this decrease was attributable to a 30% decline in utilization of targeted tests listed in Table 4. Since the shorter mean length of stay during phase II (Table 1) may not have been related to our interventions, testing frequency per day is also presented (Table 5). Despite this adjustment, the observed overall decrease was substantial (18%) and the relative contribution from the decrease in targeted vs. nontargeted tests was even more apparent (24% vs. 11%) (Table 5).

Cost Impact. Costs of tests per patient day in 1989 Canadian dollars are described in Table 6. Potential cost savings resulting from changes in frequency of testing calculated in Table 6 are based on the total number of admissions in phase II. The costs of tests not included in the list of the 20 most frequently ordered tests are underestimated due to lack of detailed costing information for a substantial number (49 of 103). The savings may be underestimated because they do not account for savings realized by other areas of the hospital as a result of our initiatives. As we have previously reported, reductions in the number of blood gases enabled redeployment of a full-time respiratory therapist, and an automated blood gas analyzer (16). It did not appear that cost savings in laboratory testing resulted in higher pharmaceutical costs. Mean drug

Table 4. Change in utilization of the 20 most frequently ordered laboratory investigations during study phases I (220 days) and II (365 days)

	Phase I (n = 647)		Phase II (n = 1236)			
Test Name	Total	Test/Admission	Total	Test/Admission	% Change	*p* Value
Tests Specifically Targeted for Reduction						
Serum osmolality	1790	2.77	1839	1.49	–46	<.001
Blood gas	22110	34.17	24109	19.51	–43	<.001[a]
CBC with diff.	1644	2.54	2185	1.77	–30	<.001
Sodium	8340	12.89	11275	9.12	–29	<.001
Potassium	8394	12.97	11778	9.53	–27	<.001
Glucose	7165	11.07	10243	8.29	–25	<.001
Chloride	6465	9.99	9604	7.77	–22	<.001
Chest radiograph	2584	3.99	3906	3.16	–21	<.001
Electrocardiogram	1341	2.07	2066	1.67	–19	<.001
Tests Not Specifically Targeted for Reduction						
Calcium	1854	2.87	2663	2.15	–25	<.01
Urine sodium	914	1.41	1423	1.15	–19	NS
Urine creatinine	921	1.42	1443	1.17	–18	NS
CPK	1194	1.85	1871	1.51	–18	<.02
PT/PTT	3319	5.13	5320	4.30	–16	NS
BUN	5061	7.82	8476	6.86	–12	NS
Creatinine	5052	7.81	8501	6.88	–12	NS
Total CO_2	3815	5.90	6988	5.65	–4	NS
CBC	2802	4.33	5168	4.18	–3	NS
Magnesium	1136	1.76	2154	1.74	–1	NS
Phosphate	1014	1.57	1926	1.56	–1	NS

% Change, change in test/admission; CBC, complete blood count; diff, differential cell count; CPK, creatine phosphokinase; PT/PTT, prothrombin time/partial thromboplastin time; BUN, blood urea nitrogen.

[a]Wilcoxon rank-sum test; all other *p* values are from *t*-tests.

Table 5. Overall changes in frequency of investigations

	Total Tests		Test/Admission			Test/ICU Day		
Phase	I	II	I	II	% Change	I	II	% Change
All Tests	103,725	148,492	160.3	120.1	–25	42.6	34.9	–18
Targeted Tests	59,833	79,688	92.5	64.5	–30	24.6	18.7	–24
Non-targeted Tests	43,892	68,804	67.8	55.7	–18	18.0	16.2	–11

ICU, intensive care unit; % Change, change in test/admission.

All tests, sum of all 123 laboratory tests collected on database; nontargeted, (all tests) minus (targeted tests); percent change calculated: (phase II – phase I)/phase I × 100.

cost per patient day was slightly lower in phase II when compared to phase I ($53.20 vs. $56.58 Canadian dollars). Table 7 shows that utilization of targeted tests per ICU day in our units has remained substantially below the baseline rates during the 3-yr period following the introduction of our approach.

Maintaining the data collection system costs ~$39,000 Canadian dollars a year. Included in this amount is a 0.7 equivalent full-time research nurse who coordinates data collection and a 0.5 equivalent full-time secretarial position devoted to data entry. Identified recoverable savings from a reduction in blood gas utilization alone were approximately twice as great as the annual cost of maintaining the data collection system.

DISCUSSION

Achieving and documenting efficiency requires information and effective management strategies. Automated access to comprehensive laboratory utilization data allowed us to identify previously unrecognized areas of waste. Furthermore, a team-based management approach with continuous monitoring of interventions produced substantial and persistent declines in testing. This result was due primarily to reductions in specifically targeted tests. There were no differences in the study populations that could explain these effects. Reduced laboratory utilization was not accompanied by increased mortality rates or protracted ICU lengths of stay (Table 1). In addition, these reductions

Table 6. Potential cost savings in 20 most frequently ordered investigations (all cost figures in Canadian dollars)

Test Name	Test Cost	Cost Per Admission		Difference	Potential Savings[a]
		Phase I (n = 647)	Phase II (n = 1236)		
Serum osmolality	4.14	11.45	6.16	5.29	6,538
Blood gas	3.73	127.47	72.76	54.71	67,622
CBC with diff	10.52	26.73	18.60	8.13	10,049
Sodium	1.17	15.08	10.67	4.41	5,451
Potassium	1.17	15.18	11.15	4.03	4,981
Glucose	1.17	12.96	9.70	3.26	4,029
Chloride	1.17	11.69	9.09	2.60	3,214
Chest radiograph	24.00	95.85	75.84	20.01	24,732
Electrocardiogram	24.17	50.10	40.40	9.70	11,989
Calcium	1.17	3.35	2.52	0.83	1,026
Urine sodium	1.17	1.65	1.35	0.30	371
Urine creatinine	1.17	1.67	1.37	0.30	371
CPK	6.03	11.13	9.13	2.00	2,472
PT/PTT	3.68	18.88	15.84	3.04	3,757
BUN	1.17	9.15	8.02	1.13	1,397
Creatinine	1.17	9.14	8.05	1.09	1,347
Total CO_2	1.17	6.90	6.61	0.29	358
CBC	4.34	18.80	18.15	0.65	803
Magnesium	4.70	8.25	8.19	0.06	74
Phosphate	0.94	1.48	1.47	0.01	12
Total		456.91	335.07	121.84	150,594

Potential Savings, cost savings over a 1-yr time period (the length of phase II); CBC, complete blood count; diff, differential cell count; CPK, creatine phosphokinase; PT/PTT, prothrombin time/partial thromboplastin time; BUN, blood urea nitrogen.

[a]This figure was derived by multiplying the cost difference per patient between phase I and phase II by the number of patients in phase II.

Table 7. Number of tests and rates of testing during phases I, II, and the two calendar years following phase II

Variable	Phase I	Phase II	1990–91	1991–92
Duration (months)	7	12	12	12
Admissions (number)	647	1236	1112	1237
Targeted test/admission	92.5	64.5	69.0	66.7
Targeted test/ICU day	24.6	18.7	18.2	17.8

1990–91: February 16, 1990 to February 15, 1991; 1991–92: February 16, 1991 to February 15, 1992.

were not offset by increased drug costs, or intervention levels as assessed by TISS.

Frequencies of testing similar to those frequencies observed in our control (phase I) patients are common; it is unlikely that our results are inflated because of extraordinary inefficiency in our units (18–21).

Previous attempts at reducing levels of testing in ICUs and other areas, using education, computer auditing, computer ordering, faculty review, and survival probabilities either separately or in combination have been less successful (12, 13, 18, 22–27). Significant, but less comprehensive reductions were achieved in a pediatric ICU where survival probabilities were used in an attempt to modify physician and nursing behavior (18). However, financial analysis was based on charges rather than actual costs, and it is possible that the effect was largely due to a nonspecific increase in cost consciousness among the staff. In our study, potential cost savings estimates (Table 6) are probably more realistic than others (28, 29), as we used actual hospital costs rather than hospital charges.

We observed a moderate overall decrease in the frequency of other investigations, suggesting that this approach may have resulted in an increase in cost-consciousness among critical care nurses and physicians. However, this effect could only account for a small proportion of overall reductions (Table 6). The basic concepts behind the control measures that we implemented have been previously described (29). Our contribution consists of a cost-effective, automated information system combined with an effective management structure that promotes sustained improvements in efficiency of test utilization.

Our initial interventions were clearly aimed at improving efficiency and reducing expenditure to justify the cost of maintaining a patient information system. In the 2 yrs after implementation of our management program, initial reductions in laboratory utilization per ICU day have been maintained (Table 7). In some cases, transient upward trends in utilization have been observed through continued monitoring and have been easily corrected by reinforcement of policies through existing educational inservice resources.

Involving all critical care team members in a cooperative management structure has generated almost universal support among the staff. All policies developed by the committee are vetted through the bedside care providers before introduction. The nurses, physicians, and respiratory therapists are instructed to override guidelines in situations where their clinical judgment suggests that patient care might be compromised. They are encouraged to report all such incidents so that policies can be appropriately modified.

We feel that our management approach is consistent with the continuous quality-improvement philosophy that has achieved considerable success in industry (30, 31). We must recognize that when we allow needless expenditures on behalf of our patients, we inevitably diminish the availability of needed resources to the patients of a colleague or to future patients of our own.

In summary, we have achieved considerable success in identifying and reducing unnecessary investigations by developing a management structure that allows us to more easily and comprehensively examine the various processes and outcomes associated with the services that we provide. We have found that encouragement of wide participation and support among our staff throughout all phases of data collection, data analysis, policy formation, and testing of interventions has proven both practical and effective.

Significantly reducing healthcare costs should first be accomplished by the identification and withdrawal of investigations and treatments that provide no patient benefit. Denying access to expensive services of established benefit may eventually be necessary. However, we must consider that such a step may be, at least in part, a consequence of the waste that we fail to identify and eliminate.

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