SUPPLEMENT ARTICLE

Outcomes of Improved Anaerobic Techniques in Clinical Microbiology

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To our knowledge, the effects of the use of improved anaerobic techniques have not been documented. We compared data on patients during 2 different time periods—the first when anaerobic cultures were done by standard techniques (the control or "before" group) and the second when anaerobic cultures were done after an intensive program to improve anaerobic techniques (IAT). The program consisted of the use of an anaerobe chamber, improved anaerobic transport and media, and education of clinicians and microbiologists. There were 74 diagnosis-related group (DRG)–matched patients in the controls and 76 in the IAT group. The average turnaround time for preliminary anaerobic data was decreased in the IAT group (124 hours per specimen for controls and 107 for IAT, $P = .001$). The cost of achieving anaerobic conditions for a plate was ~$0.09 when the anaerobic chamber was used and $0.96 when the bio-bag system was used. The crude mortality rate was 10.8% in controls and 1.3% in the IAT group ($P = .06$). The average length of stay was 10.2 days per patient in controls and 8.9 in the IAT group ($P = .91$). The average variable cost was $6865 per patient in the control group and $4432 in the IAT group ($P = .21$). The average laboratory cost was $723 per patient in the control group and $380 in the IAT group ($P = .08$). In conclusion, benefits associated with improved anaerobic testing were documented. We could expect to save >$630,000 every year with improved anaerobic processes.

Because managed-care issues (and fiscal restraints) continue to affect the functioning of microbiology laboratories, it is essential that microbiologists effectively document the outcomes of their contributions on patient care [1]. In addition, the Institute of Medicine has issued its second report calling for adherence to evidence-based medical practices [2]. There are only a few evidence-based studies that have documented the impact of microbiology data, but such studies have consistently shown the clinical and financial benefits of timely reporting, whether it be bacteriologic or viral data [3–6]. Specifically, the impact of the use of improved anaerobic techniques in the clinical microbiology laboratory has not been documented. To do this, we compared parameters on patients with anaerobic infections during 2 different time periods, the first when anaerobic cultures were done as previously (the control or "before" group) and the second when anaerobic cultures were done after a program to improve anaerobic techniques.

MATERIALS AND METHODS

Memorial Medical Center is a 450-bed community teaching hospital for Southern Illinois University School of Medicine. Its laboratory is accredited by the College of American Pathologists. In a historical cohort analysis during a 12-month period, we examined data from 2 groups of inpatients on whom anaerobic cultures were performed. One group consisted of patients whose cultured samples were processed after the initiation of an intensive program to improve anaerobic

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Table 1. Recommended methods for the collection of specimens for anaerobic culture.

Recommendation	Specimen and method of collection
Acceptable	
Dental/sinuses	Aspirated or biopsy material after decontamination
Lung	Lung aspiration or biopsy
Abdomen	Paracentesis fluid or aspiration of deep abscess by needle and syringe[a]
Female genital tract	Laparoscopy specimens, surgical specimens, or aspirations by needle and syringe
Bone	Deep aspirates of drainage by needle and syringe
Soft tissue	Surgical specimens, biopsy of tissue, deep aspirates, drainage, or pus collected by needle and syringe
Unacceptable	Nasopharyngeal, gingival, bronchial washings, expectorated sputum, vaginal or cervical samples,[b] voided urine, and surface swabs

[a] The aspirated fluid should be injected into anaerobic transport before it is sent to the laboratory.
[b] Although the use of a swab technique has been shown to be effective for obtaining viable anaerobic vaginal isolates, sampling this site anaerobically for the purpose of diagnosing infection is not recommended [12].

techniques; the control group consisted of patients with samples processed in the normal manner.

The control group had specimens processed in the clinical laboratory from 1 July to 31 December 1998. During that time, anaerobic procedures included (1) the use of anaerobic bags, (2) the use of Centers for Disease Control anaerobic blood plates (not prereduced) and thioglycollate broth for initial isolation, (3) incubation for 5 days, and (4) initial reading of plates at 5 days (or earlier if the presence of anaerobes was suspected because of the clinical impression, the initial Gram stain of the specimen, or a review of the aerobic culture). The procedure for anaerobe workup included a Gram's stain, aero-tolerance testing to confirm requirement for anaerobic conditions, colony morphology, and the use of Vitek ANI identification (bioMérieux). Antimicrobial susceptibility testing of anaerobes was not done.

The improved anaerobic technique (IAT) group had specimens processed from 1 January to 30 June 1999. Specimens were cultured for anaerobes after an intensive program to improve our anaerobic techniques. The program consisted of (1) the use of an anaerobe chamber (Anaerobe Systems); (2) the use of anaerobic transport media and prereduced Brucella blood agar, phenylethyl alcohol agar, *Bacteroides* bile esculin agar biplate (with laked kanamycin vancomycin blood agar), and thioglycollate broth (all Anaerobe Systems); (3) education for 4 technologists at a workshop on anaerobic procedures (Anaerobe Systems); (4) an intensive education of practitioners about anaerobic cultures that involved a newsletter and in-services with follow-up to nurses in surgery; and (5) strict adherence to improved guidelines from the literature for the workup of anaerobes, including criteria for the rejection of samples for which anaerobic culture had been requested [7–11]. Acceptable specimens and procedures for obtaining anaerobic cultures are given in table 1. Acceptable samples consisted of biopsies and aspirations, whereas unacceptable specimens were those from sites with anaerobic normal flora. Although performing antimicrobial susceptibility testing of anaerobes was anticipated, it was not done because none of the samples fulfilled the guidelines to indicate testing [13–15]. Patients with anaerobes isolated from blood cultures were not included in this study because procedures used on them did not differ during the 2 time periods.

Parameters analyzed. The turnaround time was estimated by subtracting the time at which the laboratory information system received verification of the first anaerobic bacteria reported on a sample from the time the sample was initially received in the laboratory. Costs (not charges) were obtained for us by the clinical data management team. Total costs were the sum of fixed direct, variable direct, and fixed indirect costs. Fixed costs are those costs that do not change with an individual patient, such as overhead and costs of administration. Variable costs are those costs associated directly with patient care, such as supplies actually used for a patient, radiological tests, or laboratory tests performed on samples from a patient.

Matching of the 2 groups by diagnosis-related group (DRG) was done for the analysis of mortality, length of stay, and costs. All patients with negative anaerobic cultures were excluded. Patients with positive anaerobic cultures during the control period were examined, and those patients who had a DRG match during the IAT period were included in the study. Initially, there were 86 DRG-matched patients in the control group and 86 DRG-matched patients in the IAT group. However, to better detect trends and patterns, our hospital (like most hospitals) excludes Health Care Financial Authority (HCFA) length-of-stay outliers, as defined by Explore (HBSI), a computer software program that involves DRG information derived from a large number of Volunteer Hospitals of America hospitals. Outliers are defined by this system as those patients whose length of stay is >2 SD for a given DRG. Twelve outliers were excluded from the control group; 10 outliers were ex-

cluded from the IAT group. In the outcome data that follow, there were 74 patients in the control group and 76 in the IAT group. Data on the outliers were examined separately.

DRG severity was determined by relative weights from HCFA published in the Federal Register [16]. Higher relative weights assigned to a DRG indicate greater severity of disease.

Statistical analysis. All analyses were performed by a doctorate-level biostatistician using the computer program SPSS (Statistical Package for Social Sciences, Inc.). The mortality rates represent all deaths in DRG-matched patients in the control and IAT groups; no DRG-group averages were used. The mortality rate was a crude rate.

Results from the preliminary *t* test indicated that the control subjects were significantly older than the IAT subjects (mean age, 57.5 vs. 47.1 years; $P < .001$). The difference between mean HCFA relative weights (2.7 for controls vs. 2.3 for the IAT group) was not significantly different ($P = .14$). Stepwise regression models were chosen for the analysis because they permit the control of these possible confounding variables [17]. Because age was significantly different, it was essential to provide a method for its control. Although the HCFA relative weight was not statistically different, controlling for any possible confounding factor with respect to specific outcomes was desirable. Therefore, stepwise models permitted age and HCFA weight to enter the regression equation if they were significantly related to the outcome variable. The patient assignment (control vs. IAT) was then entered into the regression equation only if it added significantly to the prediction of the outcome. Stepwise logistic regression was used to predict mortality, and stepwise linear regression was used to predict the other outcome variables. Once the severity of the diagnosis was taken into consideration, the age was no longer significantly related to outcome.

To determine whether unknown forces were affecting the variables studied during the 2 time periods, we compared data on all patients hospitalized during the time of the study who had the same ages as those patients in the control and IAT groups. Laboratory costs included list price for an anaerobe chamber and the cost to the institution of bio-bags.

RESULTS

The distribution of patients in each group in different DRG categories is shown in table 2. The most common DRGs were major small- and large-bowel procedures with complications and comorbidity, operating room procedures for infectious and parasitic diseases, and postoperative and posttrauma infections. The IAT group had 17.6% of the samples positive for ⩾1 anaerobes; the control group had 13.4%. Generally, infections were polymicrobial. The most common anaerobes isolated were *Peptostreptococcus, Bacteroides fragilis* group, *Prevotella,* and *Fusobacterium.* The average turnaround time for preliminary anaerobic data was 124 h for controls and 107 h for the IAT group ($P = .001$, table 3). The difference between mean HCFA relative weights (2.7 for controls vs. 2.3 for the IAT group) was not significant ($P = .14$). The crude mortality rate was 10.8% in controls and 1.3% in the IAT group ($P = .06$). The average length of stay was 10.2 days per patient in the control group and 8.9 days per patient in the IAT group ($P = .91$). The average total cost was $15,384 per patient in the control group and $10,450 per patient in the IAT group ($P = .18$). The av-

Table 2. Distribution of patients in diagnosis-related group (DRG) categories.

	No. of patients in group	
DRG description	Control	Improved anaerobic technique
Major small- and large-bowel procedure with complications and comorbidity	9	7
Operating room procedure for infectious and parasitic diseases	5	9
Postoperative and posttrauma infections	5	5
Wound debridement and skin graft	3	7
Appendectomy with complication and comorbidity	3	3
Amputation of lower limb for endocrine, nutrition, and metabolic disorders	2	4
Skin graft and/or debridement for ulcer or cellulitis with complication and comorbidity	4	1
Appendectomy without complication and comorbidity	2	3
Skin grafts and wound debridement for endocrine, nutrition, and metabolic disorders	3	3
Extensive operating room procedure unrelated to principal diagnosis	3	1
Other vascular procedures with complication and comorbidity	3	1

Table 3. Parameters examined for patients in control and improved anaerobe technique (IAT) groups.

Parameter	Control (SD)	IAT (SD)	Mean difference[a]	*P*
Mean turnaround time, h	124 (25)	107 (34)	−17	.001
Age, years	57.5 (16.7)	47.1 (20.4)	−10.4	<.001
HCFA weight	2.7 (2.5)	2.3 (1.0)	−0.4	.14
Mortality rate, %	10.8 (NA)	1.3 (NA)	−9.5	.06
Length of stay, mean days	10.2 (10.0)	8.9 (7.2)	−1.3	.91
Total cost, mean $	15,384 (19,453)	10,450 (8659)	−4934	.18
Variable cost, mean $	6865 (10,043)	4432 (3901)	−2433	.21
Laboratory cost, mean $	723 (1221)	380 (479)	−343	.08

NOTE. HCFA, Health Care Financial Authority; NA, not applicable.

[a] −, Decrease in IAT group.

erage variable cost was $6865 per patient in the control group and $4432 per patient in the IAT group ($P = .21$). The average laboratory cost (costs involving actual number of all laboratory tests, not just microbiology) was $723 per patient in the control group and $380 in the IAT group ($P = .08$).

To determine the effect of age differences, we examined data derived from all hospitalized patients aged 47 or 57 years with and without anaerobic cultures during the study period. All patients aged 47 years had a slightly increased mortality (1%) compared with all patients aged 57 years (table 4). However, the difference in mortality in the IAT and control groups was 10.5% in excess of that expected by age difference alone (table 4). All patients aged 47 years had a decreased length of stay (−0.8 days) compared with all patients aged 57 years. The difference in length of stay of the IAT and control groups is 0.5 days in excess of that expected by age difference alone. Similarly, the difference in variable costs of IAT and control patients was $1680 in excess of that expected by age difference alone.

To determine whether the same trends were also present in the outliers that were excluded from the analyses above, we analyzed data from outlier patients in the IAT and control groups (table 5). Exactly the same trends were observed in the outlier patients as were seen in the main group studied—namely, the IAT group had decreased age, decreased mortality, decreased length of stay, and decreased costs. In fact, these differences were even more pronounced in the outliers.

Figure 1 shows the trends of total cost for all patients (in the same age range as the study patients) who were hospitalized at Memorial Medical Center during the time of the study. The patients with positive anaerobic cultures (the study patients) are represented in each bar of the graph. In the first 2 bars, the study patients were a part of the larger group of hospitalized patients. In the bars with the vertical and horizontal lines, only the subset of the study patients is represented. Analysis of the trends in figures 1 and 2 shows that the study patients had a consistent reversal of the pattern for all hospitalized patients.

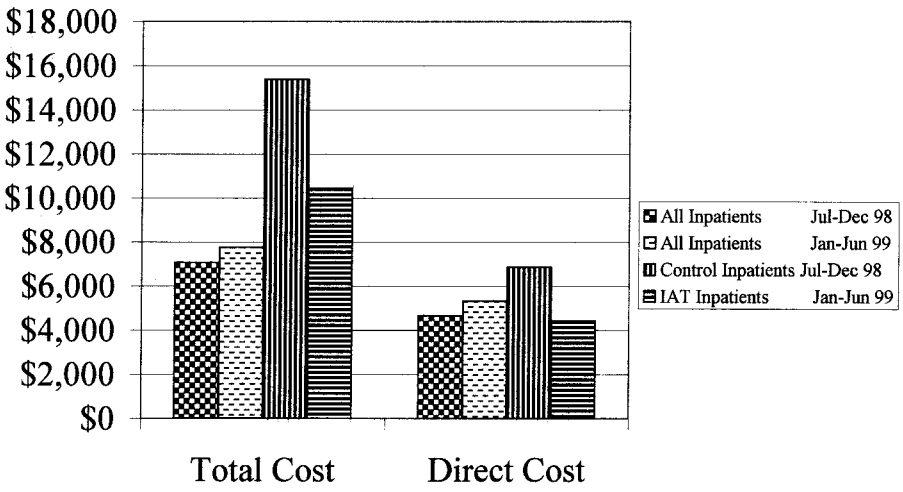

Figure 1. Comparison of costs during study periods

Table 4. Parameters examined for all patients aged 57 and 47 years (patients with and without anaerobic cultures).

Parameter	Patient data by age, years		Differences between all patients aged 47–57 years[a]	Differences between control and IAT patients[b]	Differences unexplained by age[b]
	57	47			
Mortality rate, %	1	2	+1	−9.5	−10.5
Length of stay, mean days	5.6	4.8	−0.8	−1.3	−0.5
Total cost, mean $	8135	6983	−1151	−4934	−3783
Variable cost, mean $	5478	4725	−753	−2433	−1680
Laboratory cost, mean $	414	343	−71	−343	−272

NOTE. IAT, improved anaerobe technique; NA, not applicable.

[a] −, Decrease in patients aged 47 years old; +, increase in patients aged 47 years.

[b] −, Decrease in IAT group.

Changes in neither length of stay nor costs of the 2 time periods could account for the favorable results observed after the procedural changes were implemented.

The extra technological time necessary to perform IAT was ~1 h per day. At a cost of $20 per h for technologist's salary times 365 days per year, the estimated technologist cost of IAT is $7300 per year. To estimate the cost of generating anaerobic conditions, we assumed (1) the life of an anaerobic chamber to be 7 years, (2) a cost of an anaerobic chamber of $15,000, and (3) the cost of gas and maintaining the chamber to be $1200 per year. The estimated cost of an anaerobic chamber is [$15,000 + ($1200 × 7)]/7 years =~ $3343/year (or ~$9/day). For 100 plates each day, the cost to achieve anaerobic conditions when the anaerobic chamber is used is ~$0.09 per plate ($9 per 100 plates). The cost to this hospital to achieve anaerobic conditions when a bio-bag is used is $0.96/plate.

DISCUSSION

Although it is difficult to prove a causal relationship (because of potentially uncontrolled variables in different time periods), the present study shows a consistent association between beneficial clinical and financial impact for all variables studied and improved anaerobic techniques. These differences occurred when the trend for all patients in the hospital was that of slightly increasing costs and length of stay (figures 1 and 2). Although these data are not conclusive, they do provide preliminary evidence of the benefits associated with IAT.

Length-of-stay outliers were excluded from our analysis because the hospital (like most) excludes outliers to eliminate bias. If we had included these outliers, the benefits of IAT would have increased substantially (table 5).

Although the benefits did not achieve statistical significance, each indicated a trend toward lower costs and increased benefits for the IAT group. The *P* values for mortality rate (.06) and mean laboratory costs (.08) were near a statistically significant level ($P = .05$). Of particular note is the decrease in variable costs of $2433 per patient in the IAT group. Administrators consider these variable costs responsible for the actual cost savings realized by the hospital.

The hospital has ~250 inpatients annually who have positive

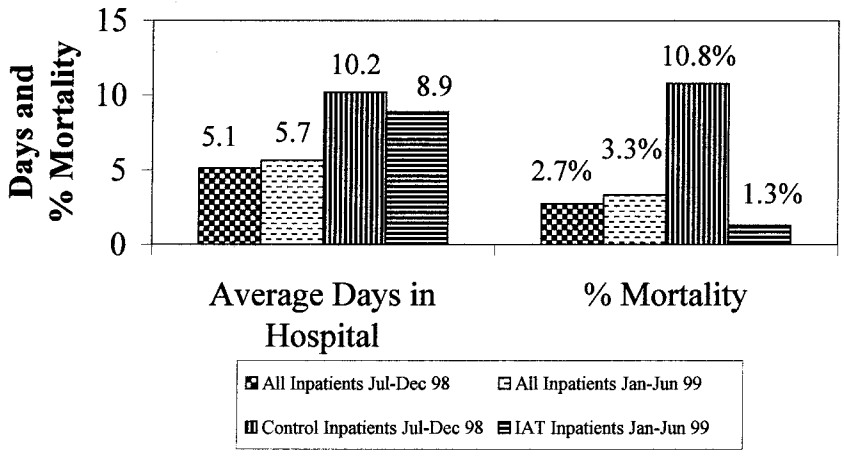

Figure 2. Comparison of trends in length of stay and mortality during study periods

Table 5. Parameters examined for outlier patients in control and improved anaerobe technique (IAT) groups.

Parameter	Control	IAT	Mean difference[a]
Age, years	64.7	52.7	−12
Mortality rate, %	33	10	−23
Length of stay, mean days	71.6	57.5	−14.1
Total cost, mean $	105,135	90,257	−14,877
Variable cost, mean $	49,721	44,276	−5445

[a] −, Decrease in IAT group.

anaerobic cultures. On the basis of variable costs from the patient outcome data, this hospital could expect to save $608,250/year ($2433 in variable costs saved per patient × 250 patients) by performing improved anaerobic studies.

The performance of IAT had 2 effects on the laboratory budget: (1) additional technologist time necessary and (2) the costs of generating anaerobic conditions by different methods. The laboratory could expect to save $31,755 ([$0.96, the cost of achieving anerobiasis by bio-bag per plate − $0.09, the cost of achieving anerobiasis by anaerobic chamber/plate] saved per plate × 100 plates/day × 365days/year) on supplies using an anaerobic chamber compared with bio-bags to achieve anaerobic conditions. Subtracting the cost of the increased technologist time ($7300) from the decreased costs ($31,755), the overall impact of improved anaerobic techniques to the laboratory itself is $24,455 saved per year.

An additional advantage of the use of an anaerobic chamber is that it increases the likelihood of isolating and identifying anaerobes, because manipulation of the organisms in ambient air is unnecessary, unlike the procedures that use bio-bags or anaerobic jars. In fact, the isolation rate of IAT was slightly more (4.2%) in the IAT group than in the control group. Furthermore, procedures for working up anaerobes can be batched in an anaerobic chamber without loss of viability of the organism, unlike bio-bags or anaerobic jars. This allows more efficient use of a technologist's time. The only disadvantage of IAT was that it took more technologist time.

The present study did not investigate exactly how patient care was changed by IAT. More-specific details of anaerobes, such as the presence of *B. fragilis* rather than "mixed anaerobes," were reported. Rarely, an infectious disease physician indicated that our reporting for anaerobes seemed improved. It is likely that the major impact was that the more rapid turnaround time both for the presence of anaerobic bacteria in general (such as "mixed anaerobes") and specific pathogens (such as *B. fragilis*) caused physicians to prescribe antibiotics with anaerobic coverage earlier. This, in turn, led to earlier, more effective anti-infective therapy for patients.

In conclusion, laboratory, clinical, and financial benefits were associated with IAT. Given the cost savings from variable costs ($608,250) and the cost savings in the laboratory from the use of the anaerobe chamber ($24,455), the expected cost savings of IAT is $632,705 annually.

Acknowledgments

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