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Cost-effective Reduction of Neuromuscular-blocking Drug Expenditures

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Background: **Anesthetic drug expenditures have been a focus of cost-containment efforts. The aim of this study was to determine whether expenditures for neuromuscular-blocking agents could be reduced without compromising outcome, and to determine whether such a cost-effective pattern of neuromuscular blocker use could be sustained.**

Methods: **Education, practice guidelines, and paperwork barriers were used to persuade anesthesiologists to substitute low-cost neuromuscular-blocking drugs (pancuronium or a metocurine–pancuronium combination) for a more costly neuromuscular-blocking drug (vecuronium). Neuromuscular-blocking drug use in all patients during a historical control period (6 months; n = 4,804) was compared with that during two consecutive 1-yr periods of intervention (n = 9,761/n = 10,695). Expenditures for vecuronium and for all neuromuscular-blocking drugs were compared for the control and intervention periods. The rate of complications related to neuromuscular-blocking drugs was determined by an ongoing continuous quality improvement program.**

Results: **Vecuronium use decreased by 76% during the first and second yr of intervention, compared with the historical period ($P < 0.01$). The cost of neuromuscular-blocking drugs decreased by 31% ($P < 0.01$) and 47% ($P < 0.01$) for the first and second yr, respectively. The complication rate related to neuromuscular-blocking drugs was 0.081% in the historical period and 0.11% and 0.093% during the intervention periods ($P = 0.29$ and 0.41).**

Conclusion: **Practice guidelines, education, and paperwork barriers used together substantially reduced the expenditures for neuromuscular-blocking drugs for 2 yr without adversely affecting clinical outcome. (Key words: Neuromuscular relaxants. Neuromuscular blocking agents: pancuronium; pancuronium-metocurine; vecuronium. Economics, drugs. Anesthesia. Quality assurance.)**

THE increasing cost of health care has stimulated many efforts to control or reduce expenditures. One area that has received substantial attention is the cost of pharmaceutical products. The issue of cost control has been a focus of recent interest in anesthesiology.[1-4] Various methods have been used to control expenditures for anesthetic agents, including education, practice guidelines, and formulary restrictions.[3,5-7] However, there has been little effort to determine if reductions in drug expenditures are actually cost-effective (*i.e.*, producing a cost savings with an equal or better outcome). This investigation prospectively evaluated a program for drug expenditure reduction and the effect on outcome of anesthesia care.

When this study was begun, vecuronium accounted for 70% of our costs for neuromuscular blockers (NMBs). Because the average procedure duration in our academic medical center practice is 191 min, the shorter duration of action of vecuronium compared with pancuronium did not appear to be cost-effective. We persuaded clinicians to replace vecuronium with pancuronium or a mixture of pancuronium and metocurine and then observed the effect on NMB expenditures and the outcome of anesthetic care.

Methods

We obtained approval for this study from the institutional review board of our institution. The investigation

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was done in four phases: historical, survey, education, and restriction. During the 6-month historical period (December 1992–May 1993), data concerning use and cost of NMBs were obtained retrospectively from our operating room pharmacy. During the survey period (June 1993–September 1993), clinicians were required to complete a questionnaire before receiving vecuronium from the operating room pharmacy. The purpose of this questionnaire was to focus attention on the indications for using vecuronium by requiring that the clinicians state the reason for each use. After completion of the survey period, vecuronium was dispensed without a questionnaire for 2 months while the survey was analyzed and practice guidelines were developed. During this educational period, discussions occurred to promote group participation; clinicians were informed about the expenditure-reduction strategy and were encouraged to substitute pancuronium for vecuronium. Use of a metocurine–pancuronium mixture (1.0 mg/ml metocurine + 0.25 mg/ml pancuronium) was suggested for those situations in which minimal hemodynamic side effects were considered essential.[8] The metocurine–pancuronium mixture resembles vecuronium in that there are minimal hemodynamic side effects; the duration of action is shorter than pancuronium and somewhat longer than vecuronium.[9] The hospital's acquisition cost of the metocurine–pancuronium mixture for intubation was approximately $6.00 compared with $18.85 for vecuronium. The operating room pharmacy made metocurine available in prefilled syringes, to which pancuronium could be added by clinicians to constitute the appropriate mixture.

The practice guidelines for vecuronium recommended that vecuronium be used only for the following indications:

1. Rapid sequence induction of anesthesia required in a patient for whom the use of succinylcholine is contraindicated.
2. Case duration of less than 1 h.
3. Other special clinical conditions (to be specified in each case).
4. Research or teaching.

After the educational period, there were two consecutive year-long restriction periods (December 1993 to November 1994 and December 1994 to November 1995). During these 2 yr, vecuronium use was restricted to these practice guidelines, and completion of a form was required to obtain vecuronium from the operating room pharmacy.

Patient outcomes were determined through our previously described continuous quality improvement (CQI) program.[10] This program is based on self-reporting of critical incidents and adverse outcomes. Anesthesia providers report cases by marking a special code on the anesthesia record. Cases are reviewed daily by the CQI coordinator, who interviews providers to obtain relevant details. Reported cases are then reviewed weekly by the anesthesia CQI screening committee according to a structured evaluation process. The results of this review are stored in a computerized database. For the purposes of this study, problems related to neuromuscular blockade were extracted from the database and examined in detail by the investigators. Monthly rates of complications associated with NMBs were calculated.

Use of all NMBs was measured in vials used per month from the operating room pharmacy dispensing records. In our hospital, once a drug vial is opened, any drug that is not administered to an individual patient is discarded. Expenditures for all NMBs and vecuronium were calculated by multiplying the vials per month by the price per vial paid during that month. Expenditures were expressed as expenditures per month.

The following hypothesis was tested: Use of vecuronium, expenditures for vecuronium, and expenditures for all NMBs combined would decrease between the historical and all later periods, without an increase in complications related to neuromuscular blockade. Statistical comparisons of expenditures and use of all NMBs combined and of vecuronium were made using a one-tailed t test. Due to the low rate of adverse outcomes and the expectation that rates would increase during the restriction and follow-up periods, comparisons of complication rates between the historical period and the survey and restriction periods were made using the Mann-Whitney test, with Monte Carlo one-tailed significance calculated from 10,000 sampled tables.[11]

Results

The demographics of our anesthesia practice were unchanged during the study (table 1) and the overall use of NMBs was constant (fig. 1). The use of vecuronium declined by 58% during the survey period and by 76% during both years of the restriction period, by comparison with the historical period (fig. 1; $P < 0.01$). As a consequence of reduced vecuronium use, the total annualized expenditures for NMBs decreased by 35% during the survey period

Table 1. Practice Demographics

Year	ASA (% 1/2/3/4/5)	Case Time (mean, h:min)	Age (mean, yr)	Total Cases	General Anesthesia (%)	Regional Anesthesia (%)	Combined General/ Regional (%)
1993	20/44/29/7/1	3:34	45.3	11,840	60	20	9
1994	21/44/29/6/0	3:26	44.2	12,481	61	19	9
1995	17/43/33/6/1	3:20	45.3	13,461	61	18	8

and by 31% and 47% during the 2 yr of the restriction period, respectively, by comparison with the historical period (fig. 2; $P < 0.01$). The annualized savings were about $34,000 for the first yr and $51,000 for the second yr of the restriction period.

The problems related to NMBs reported to the CQI program all involved prolonged neuromuscular blockade, defined as failure to fully reverse neuromuscular blockade at the completion of surgery. There were no problems reported to the CQI program involving cardiovascular side effects of NMBs. The consequences of prolonged neuromuscular block were prolonged recovery room stay and the short-term use of a mechanical ventilator in the recovery room for some but not all of the affected patients. Duration of recovery room stay for patients with prolonged neuromuscular blockade was not significantly different for vecuronium (mean = 156 min; SD = 80 min; range, 80–265 min) and pancuronium or metocurine–pancuronium (mean = 123 min; SD = 64 min; range, 24–280 min). There were no significant differences in the rate of prolonged neuromuscular blockade between the historical period (0.81 per 1,000 cases) and the survey period (2.3 per 1,000 cases; $P = 0.14$), the first restriction yr (1.2 per 1,000 cases; $P = 0.29$), or the second restriction yr (0.93 per 1,000 cases; $P = 0.41$; table 2).

Of the 34 cases of prolonged neuromuscular blockade, 11 involved shorter-acting NMBs (atracurium, mivacurium, vecuronium, and succinylcholine), 20 involved longer-acting NMBs (metocurine, metocurine–pancuronium, pancuronium), and 3 involved combinations of shorter- and longer-acting NMBs.

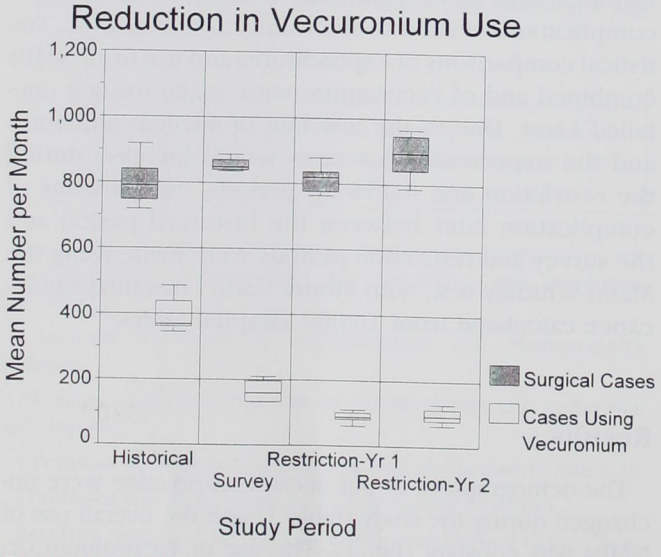

Fig. 1. Monthly number of surgical cases and the cases in which vecuronium was used are shown for the historical, survey, and restriction periods. The mean is indicated by a horizontal line, ± SD by the box, and the extreme high and low values by the bars. Vecuronium use was reduced by 76% between the historical period and both years of the restriction period ($P < 0.01$).

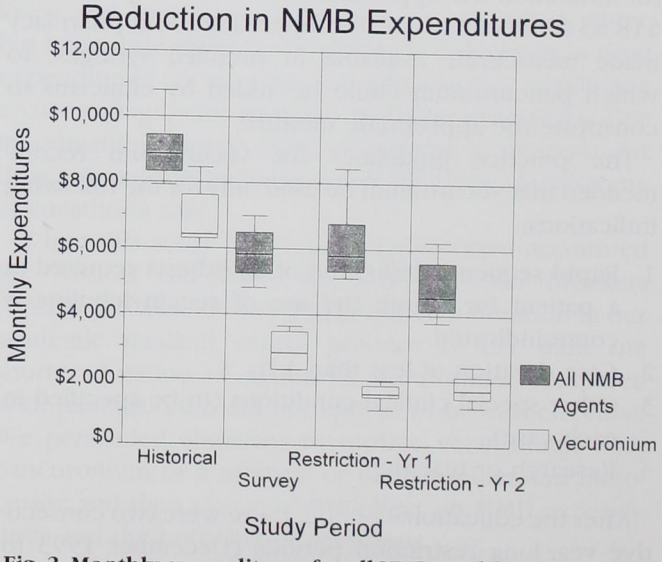

Fig. 2. Monthly expenditures for all NMBs and for vecuronium are shown for the historical, survey, and restriction periods. The mean is indicated by a horizontal line, ± SD by the box, and the extreme high and low values by the bars. Mean monthly expenditures for all NMBs were reduced by 31% and 47% for the historical period and the 2 yr of the restriction period, respectively ($P < 0.01$).

Table 2. Cases of Prolonged Neuromuscular Blockade from the Continuous Quality Improvement Database

Time Period	Atracurium	Metocurine	Metocurine–Pancuronium	Pancuronium	Vecuronium	Succinylcholine	Other	Total	Mean Monthly Rate/1,000 Cases (upper 95% confidence interval)
Historical (n = 4,804) (12/92–5/93)					3		1*	4	0.81 (1.9)
Survey (n = 3,419) 6/93–9/93			1	5	1	1		8	2.3 (6.4) $P = 0.14$†
Restriction Year 1 (n = 9,761) 12/93–11/94	1	1	2	2		2	4‡	12	1.2 (2.2) $P = 0.29$†
Restriction Year 2 (n = 10,695) 12/94–11/95			4	5	1			10	0.93 (1.4) $P = 0.41$†
Total (n = 28,679) 12/93–11/95	1	1	7	12	5	3§	5	34	

* Vecuronium + mivacurium.

† *P* values are in comparison with historical period.

‡ Metocurine–pancuronium + mivacurium (2 cases); atracurium + magnesium sulfate infusion (1 case); metocurine–pancuronium + succinylcholine (1 case).

§ Single bolus of succinylcholine (1 case); succinylcholine infusion (2 cases).

Discussion

Substitution of low-cost NMBs for vecuronium resulted in 31% and 47% reductions in expenditures for NMBs during the restriction and follow-up periods. The total amount saved was $34,000 during the first restriction yr and $51,000 during the second yr, compared with expenditures during the historical period. The minimum amount saved per patient when pancuronium was substituted for vecuronium was $17.51 (the cost difference between a vial of vecuronium and a vial of pancuronium; acquisition prices were stable during the study). The extent of expenditure reduction was similar to that reported by Szocik and Learned[5] (38%) and Becker and Carrithers[12] (26%). Szocik and Learned encouraged the substitution of pancuronium for atracurium, doxacurium, and pipecuronium. In our practice, atracurium, doxacurium, and pipecuronium were not extensively used and did not contribute substantially to total NMB expenditures.

The larger reduction in expenditures during the second restriction yr compared with the first restriction yr is explained primarily by a decrease in use of metocurine, which was unavailable from the manufacturer during part of the restriction period (September to November 1995). Metocurine is more costly than pancuronium.

The costs of administering this program were insignificant. The pharmacy staff of our operating room satellite pharmacy incorporated the paperwork and metocurine syringe preparation into their routine; no increase in pharmacy staff or salaries was required. Our normal procedure requires anesthesiologists to obtain drugs from the pharmacy for each case. The only additional burden on the anesthesiologist was to complete a form to obtain vecuronium, which required less than 1 min.

There did not appear to be substitution of inhalational anesthetics for NMBs, which might have offset the savings from NMBs. Hospital expenditures for inhalational agents were constant during the study.

The NMB cost savings occurred as the result of education, practice guidelines, and a paperwork barrier to obtaining vecuronium from the operating room pharmacy. The importance of each of these components in the decision to use a particular NMB is impossible to know. Greco and Eisenberg[13] suggested that interventions that use more than one method are most successful in changing physicians' practices. Vecuronium use was reduced substantially during the survey period, before introduction of practice guidelines, suggesting that the paperwork barrier to obtaining vecuronium was a key factor in the reduction of vecuronium use. Blakely

and Artman[6] reported that this tactic also worked well in their hospital. Horrow and Rosenberg[14] reported that affixing price stickers to drug vials had only minimal effect on practice behavior, suggesting that something more than simple cost awareness is necessary to alter physician behavior. Szocik and Learned[5] and Becker and Carrithers[12] relied on educational programs to persuade clinicians to reduce drug costs. However, education alone may not be sufficient to obtain lasting effects. Johnstone and Jozefczyk[7] reported that an intensive educational program resulted in a 23% reduction in expenditures for all anesthetic drugs during a 2-month period, but the program lost effectiveness, and expenditures returned above their baseline levels due to a dramatic increase in lobbying by drug company representatives.

This study was done in a university medical center, with care provided by attending anesthesiologists supervising residents and certified nurse anesthetists. There is a substantial turnover of personnel, as expected in a residency training program. Our approach for modifying clinical behavior, including education, practice guidelines, and a paperwork barrier may not be necessary in every practice setting. For example, in a cohesive private group practice, a set of practice guidelines may be sufficient, without the need for a paperwork barrier. The average procedure lasts 191 min in our institution. Shorter-acting NMBs may be more cost-effective in a practice with substantially shorter procedures.

Substitution of low-cost drugs for costly drugs may result in worse outcomes or complications if the more costly drugs are more effective or safer. The costs of treating complications may negate or exceed the savings gained by drug substitution, and poorer outcomes may not be acceptable if the community places a high value on quality of care. The CQI data suggests that outcomes were not significantly altered by substitution of low-cost, longer-acting NMBs for vecuronium. The rate of prolonged neuromuscular blockade did not increase significantly during the survey or restriction periods, despite a dramatic decrease in the use of vecuronium. For those patients with prolonged neuromuscular blockade, the duration of recovery room stay did not vary significantly between vecuronium and pancuronium or metocurine-pancuronium. The prolonged neuromuscular blockade that did occur was associated with short-acting (14 cases) and longer-acting (20 cases) NMBs. Succinylcholine, the NMB with the shortest duration, was implicated in three cases of prolonged neuromuscular blockade. Therefore, the most important finding of this investigation was that significant expenditure reductions for NMBs were accomplished without decreasing the quality of care or anesthetic outcome.

Bevan *et al.*[15] studied train-of-four monitoring in the recovery room and found a high incidence of patients with a train-of-four ratio <0.70, despite administration of reversal agents. The incidence of impaired neuromuscular activity was significantly greater after pancuronium compared with atracurium or vecuronium. These results could be interpreted to imply a greater margin of safety for short-acting NMBs. In contrast, Kopman *et al.*[16] did not find a significant difference between pancuronium and mivacurium in the proportion of patients with train-of-four ratios < 0.70 after reversal. Although the possibility remains that shorter-acting NMBs offer a greater margin of safety with respect to incomplete reversal, we could not detect a significant effect on clinical outcome based on CQI data.

The problems with NMBs reported to our CQI program were all related to prolonged neuromuscular blockade. However, hemodynamic side effects are also a potential concern with certain NMBs. Despite theoretical considerations, there were no reports to our CQI program of hemodynamic side effects attributed to pancuronium or any other NMB.

There is a potential shortcoming in CQI data that is derived from spontaneous, voluntary reporting of anesthetic complications.[17,18] Although educational efforts have resulted in a high level of clinician involvement in the CQI process, it is inevitable that some cases will not be reported because clinicians will inadvertantly fail to properly designate a case for review by the CQI committee. Therefore, the reported rate of problems related to NMBs may underestimate the true rate. We would anticipate a bias toward increased adverse event reporting during the survey and restriction periods because the new practice guidelines and education would increase practitioner awareness of NMB complications. Therefore, we expected that the apparent rate of complications might increase during the survey and restriction periods, even if there was no change in the true complication rate. The complication rate increased slightly during survey and restriction periods compared with the historical period (table 2), but the variations in complication rates were not statistically or clinically significant.

In conclusion, this study shows that expenditures can be decreased by influencing anesthesiologists to substitute less costly NMBs for vecuronium, and that the savings can be maintained during a period of 2 yr. The

techniques used to modify clinician behavior included education, practice guidelines, and paperwork barriers. Importantly, the savings in drug costs were not negated by an increase in complications related to drug substitution, according to outcome data from our CQI program, or by increased use of volatile anesthetic agents in place of NMBs. Therefore, substitution of pancuronium or pancuronium-metocurine for vecuronium was truly cost-effective.[19] The techniques used in this study are applicable to other drugs. Although vecuronium was selected as the "costly" target drug in this study, the costs of drugs change frequently, and today's costly drug may become tomorrow's low-cost drug as patents expire and new drugs are introduced. Thus drug-expenditure management is a dynamic process.

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