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Economic Evaluation of Four Drug Administration Systems in Intensive Care Units in Colombia

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ABSTRACT

Introduction: Intensive care units (ICUs) are the most frequent setting for serious medical errors, which not only have serious health consequences but also an economic impact. In this article, using a theoretical model, we evaluate four medication administration systems: conventional preparation by nursing staff, MINIBAG Plus delivery system, compounding center preparation, and premix drugs. **Methods:** We designed a decision tree model from a third-party payer perspective, and the time horizon of the acute event. Local costs, in Colombian pesos (US $1 = 1784 COP$), were obtained from tariff manuals, medication costs from Sismed information system, and clinical variables from the published literature, and uncertainty was dealt with by an expert panel. The drug used for the model was dopamine. **Results:** Average costs for each dopamine dose delivered were $46,995 for premix, $47,625 for compounding center, $101,934 for MINIBAG Plus, and $108,870 for drug prepared in the ICU. The variability of these results is higher for compounding center than for premix, and even higher for MINIBAG Plus and nurse delivery. **Conclusions:** The use of premix drugs can be a cost-saving strategy, which decreases medical errors in drug administration in the ICU, particularly if it is part of an integral error reduction program.

Keywords: drug administration schedule, drug delivery systems, economics, intensive care units, medication errors.

Introduction

The aphorism *primum non nocere*—above all, do no harm—included in the Hippocratic Oath has regained particular relevance 2500 years later. In health care systems worldwide, effectiveness, as the final goal for therapeutic interventions, has been placed in a balance in which safety and cost also play primary roles [1]. Much has been written on medical error (a mistake by any health care team member, not only physicians) since the controversial book *To Err Is Human* was published [2], which showed how errors could lead to 1 million injuries and about 100,000 deaths per year in the United States alone.

Nowhere else is the "error" issue as sensitive as in the intensive care unit (ICU) [3]. The combination of high complexity, interventional diversity, and critically ill patients make the ICU particularly vulnerable to medical errors [4]. A multinational trial that included 205 ICUs showed 38.8 "incidents" per 100 patient-days in five domains: intravenous (IV) lines and accesses, airway management, equipment, alarms, and medications [5]. It is estimated that 1 of every 10 IV infusions at the ICUs are either erroneously prepared or administered [3]. When only medication errors are considered, the estimation is 10.5 incidents per 100 patient-days in the prescription and administration stages [5].

Error prevalence at ICUs is uncertain; estimation of the frequency of errors during drug administration ranges between 1.2 and 947 per 1000 patient-days in adults [3]. Such range results from medical error reporting mechanisms; for example, in independently reported trials, the prevalence is lower. An example is the study by Taxis and Barber [6] in which 1328 patients from 113 ICUs in 27 countries were included, with Brazil and Argentina as the only Latin American representatives. Types of errors evaluated were omissions, wrong drug, wrong dose, wrong administration route, and improper dosing time. The estimated prevalence in this study was 74.5 errors per every 100 patient-days; interestingly, 19% of the participating ICUs reported no errors during the study period.

The incidence of errors with injectable medications is higher than with other forms of medications [7]. Of the five stages in IV medication administration (prescription, transcription, dispensation, administration, and monitoring), the drug administration phase is most prone to errors [8], which can be further classified as follows: omission, inadequate dosing, inadequate concentration, wrong medication, incorrect technique, incorrect administration route, improper administration rate, incorrect dosing time, and wrong patient. Consequences of these errors are also classified, in increasing severity, with a lettered-scale that ranges from B to I, with B corresponding to a wrong medication that is not administered and I to an error that

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Table 1 – Classification of medical errors by Calabrese et al. [9], as per error type clustering used by the authors and the corresponding incidence probability (once an error has occurred).

Category	Definition	Error type	Probability (%)	Reference
A	*Quasi* error			
B	Wrong drug, not administered	No harm	92	[10]
C	Medication administered without consequences			
D	Monitoring required but no symptoms	Mild harm	6.33	[10]
E	Symptoms development, management required	Moderate harm	1.44	[6]
F	Hospital stay is required or increased			
G	Permanent consequences develop	Severe harm	0.42	[6]
H	Risk of death (anaphylaxis, cardiac arrest)			
I	Death	Death	0.21	[6]

results in the patient's death (Table 1). The time horizon of medication error is, therefore, quite variable. Most errors lead to either minor harm or no harm at all, while it has been estimated that about 2% of the errors cause significant injuries to patients [9].

Calabrese et al. [9] proposed another error classification considering both drug administration route (e.g., subcutaneous administration, IV bolus, and IV infusion) and drug class (e.g., antibiotics, sedatives, vasopressors, and insulin). Despite the fact that no other potential medication errors (microbiological contamination, compounding errors such as wrong dilutant or drug concentration miscalculation) were considered in this trial, error rate exceeded the one reported in the previously described study as it reached 74.5 errors per 100 patient-days. Overall, an error occurs in about 7% of all parenteral drug administrations [10]. Medication dosing errors (118 of 861 recorded errors) had the most serious consequences as they resulted in permanent harm in three patients and in the death of other three patients. Other studies [3,11] report even higher error rates regarding medication administration at the ICUs, reaching up to 1 daily error per patient, on average [12].

Apart from having severe consequences on the patients' health, errors have serious financial consequences [13]. In a sample of ICU patients in Switzerland (n = 333), Nuckols et al. [14] showed preventable IV drug administration–related adverse events in 94 patients (28%). Such adverse events were associated with an extended hospital stay (mean 4.8 days) as well as with increased costs (mean US $4500) versus the control group.

The objective of this study was to develop an economic evaluation model to estimate the costs and outcome impact of four different IV drug administration systems (assuming the same drug) at the ICU setting in Colombia.

Methods

We designed a decision tree–type economic model using TreeAge Pro Healthcare 2009 (Fig. 1). Four alternatives for IV drug delivery were considered: use of premix drugs, compounding center preparation, bedside preparation at the ICU by a nurse (but using a buretrol set), and MINIBAG Plus use (flexible closed system bag with a vial adaptor—a point-of-care activated device). Baseline data included in the model were extracted from international medical journal publications (see Table 1) and subsequently discussed and validated by an expert panel independently selected by the investigators (with no sponsor participation). The panel was composed of an internal medicine specialist, a surgeon, two physicians specialized in pharmacology, and a pharmacist. Dopamine was selected as the drug for the model because it shows a larger cost difference between premix and competitors. We used a third-party payer perspective (Colombian health system), and the time horizon was the length of ICU stay (which is similar to that reported in the literature); no discount rate was applied because the period of analysis was shorter than 1 year. Costs are in Colombian pesos (COP $) as for 2012 (as reference, the exchange rate for July 2012 was US $1 = COP $1784).

Model Assumptions

The main assumption of the model is that error incidence rates at Colombian ICUs are similar to those published elsewhere. Calculations are based on a "typical" ICU adult patient.

Error risks

To estimate error risks, a literature review was carried out using MeSH "Medication Errors," "Drug Administration Schedule," "Drug Delivery Systems," and "Intensive Care Units" as search criteria. A total of 272 abstracts were reviewed; 27 articles were selected for full-text review, of which 20 [4,5,9–11,13–27] reported error rates. Among 113 ICUs from 27 countries, the only data from the region came from Brazil [17] and from 6 ICUs (3 Argentinean and 3 Brazilian) included in the study by Valentin et al. [5]. Error probabilities used in the model (based on Nuckols et al. [14]), for each individual drug administration, were as follows: 0.01 for compounding center preparation (by pharmacists), 0.08 for bedside preparation by nursing staff, 0.03 for MINIBAG Plus, and 0.0027 for premix drugs. For our base-case scenario, we selected the error rates of Taxis and Barber [6] and Klopotowska et al. [10] because they were on the conservative side (we preferred to underestimate the risk) and because they include a wide range of error consequences. Only one reference [15] included error rates for compounding centers versus premix medication. For the sensitivity analysis, we arbitrarily assumed a wide range after discussions with our expert panel. In error probabilities, we considered it unpractical to convert rates to probabilities. We used rates as probabilities because of the short time frame.

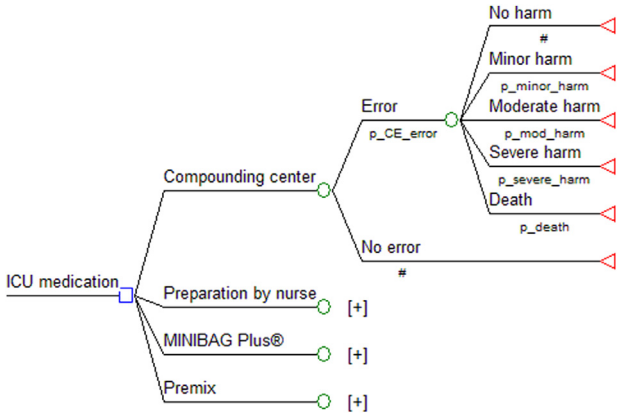

Fig. 1 – Decision tree outline. Errors include preparation-related, contamination, and biological risk errors. ICU, intensive care unit.