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Cost-Effectiveness Analysis of an Automated Medication System Implemented in a Danish Hospital Setting

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ABSTRACT

Objectives: To evaluate the cost-effectiveness of an automated medication system (AMS) implemented in a Danish hospital setting. **Methods:** An economic evaluation was performed alongside a controlled before-and-after effectiveness study with one control ward and one intervention ward. The primary outcome measure was the number of errors in the medication administration process observed prospectively before and after implementation. To determine the difference in proportion of errors after implementation of the AMS, logistic regression was applied with the presence of error(s) as the dependent variable. Time, group, and interaction between time and group were the independent variables. The cost analysis used the hospital perspective with a short-term incremental costing approach. The total 6-month costs with and without the AMS were calculated as well as the incremental costs. The number of avoided administration errors was related to the incremental costs to obtain the cost-effectiveness ratio expressed as the cost per avoided administration error. **Results:** The AMS resulted in a statistically significant reduction in the proportion of errors in the intervention ward compared with the control ward. The cost analysis showed that the AMS increased the ward's 6-month cost by €16,843. The cost-effectiveness ratio was estimated at €2.01 per avoided administration error, €2.91 per avoided procedural error, and €19.38 per avoided clinical error. **Conclusions:** The AMS was effective in reducing errors in the medication administration process at a higher overall cost. The cost-effectiveness analysis showed that the AMS was associated with affordable cost-effectiveness rates.

Keywords: automated dispensing, bar code–assisted medication administration, cost analysis, cost-effectiveness, medication administration, medication errors, patient safety.

Introduction

The effective and safe handling of medicines is an ongoing concern with many health care services. The primary concern is patient safety as new services are tested and evaluated. Nevertheless, with increasing health care costs the cost-effectiveness and budget impact of new initiatives become more important when decision makers must prioritize scarce resources and maximize health improvement [1].

The medication administration process from the prescription to the administration of medicine affects a substantial part of the hospitalized population. Medication errors have been reported in approximately 5.7% (range 0%–49%) of all medication administrations [2]. Medication administration errors are not always harmful, but are associated in a varying degree with adverse drug events (ADEs) potentially leading to inconvenience, disability, or death [3–6]. Therefore, ADEs may result in longer hospitalization or re-admission, which increases the costs not only for the patient but also for health care providers.

Different technologies have been found to influence the medication error rate in varying degrees, representing possible cost savings. International studies have suggested that patient identification and alignment with administration records through bar code medication administration (BCMA) can reduce the number of medication administration errors [7–9]. Automated dispensing is another previously tested technology, but studies have so far shown inconsistent results [10–12]. Technologies and interventions that reduce medication error rates must also be evaluated for their cost-effectiveness because those, which are cost-prohibitive, are not sustainable. Cost-effectiveness evaluations provide essential information for determining whether an intervention represents "good value for money" and for prioritizing among different interventions and technologies.

Vermeulen et al. [13] studied the cost-effectiveness of an electronic medication order entry system for hospitalized patients and concluded that the extra cost of preventing a medication error was acceptable. The cost-effectiveness results were, however, geographically affected by threshold value variations by country, region, or hospital, which is a general concern to the generalizability, indicating the need for further studies to confirm this tendency. In their review from 2012,

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de Rezende et al. [14] investigated the methods of economic evaluation in patient safety. They found that most studies focused on the economic burden of ADEs and only a few studies provided a full economic evaluation. de Rezende et al. concluded that to strengthen the knowledge base on practices for improving patient safety and understanding the economic consequences of different interventions, more economic evaluations are needed.

The objective of this study was to evaluate the cost-effectiveness of an automated medication system (AMS) implemented in a Danish hospital setting. The AMS included three functional elements: an electronic medication administration record (eMAR), an automated medication dispensing system, and a BCMA.

Methods

Design and Setting

The economic evaluation was performed using data from a prospective, controlled, before-and-after study of the effects of an AMS. The effectiveness study, as described in Risør et al. [15], was conducted in two hematological wards—one participated as the intervention ward and the other as the control ward. The study took place at a Danish university hospital from May 2013 to February 2014 with baseline measurements and follow-up after 4 months. Resource utilization and cost data were collected before and after implementation of the intervention and have not been published previously.

Intervention

The AMS implementation in the study comprised three elements: 1) a pharmacist-performed technical control of prescriptions in the eMAR before forwarding orders to an automated dispensing machine; 2) automated unit dose (one dose of medication per dose bag) dispensing of medication packed for individual patients and delivered every 24 hours; and 3) BCMA with bedside bar code scanning using a personal digital assistant (PDA) of the packed dosage and patient wristband before administration [15]. The AMS is described in detail in File 1 in Supplemental Materials found at http://dx.doi.org/10.1016/j.jval.2017.03.001.

The automated dispensing machine was located in the hospital pharmacy, making it possible to provide prepackaged medication to multiple departments.

Data Collection

Measurement of effects

The primary outcome measure was the number of errors in the medication administration. The proportion of errors was determined by dividing the number of doses identified with one or more errors by the number of opportunities for error. In accordance with the work by Allan and Barker [16], the "opportunities for errors" were defined as the sum of doses given plus doses prescribed but omitted and the number of opportunities for error corresponding to the total number of doses.

An error in the medication administration process was defined as "the administration of a dose of medication that deviated from the eMAR prescription, from standard hospital policy, or from written procedures." The medication administration errors were further divided as follows:

1. *Clinical errors*: The patient did not receive the medication as prescribed in the eMAR.
2. *Procedural errors*: These are deviations from written procedures or guidelines. Deviations could potentially, but not necessarily, lead to a clinical error [17].

Table 1 outlines and defines the error types included in this study.

The number of observations needed to ensure sufficient statistical power was estimated by a power calculation assuming an error rate of 0.22, a power of 80, and an expected reduction in errors of 30%. This indicated a required sample size of 511 observed doses at each ward in both data collection periods.

Each observation period was 3 weeks and was carried out before the implementation of the AMS and at the 4-month follow-up. Measurement of clinical and procedural errors was done by nondisguised direct observation of nurses in the medication administration process by three dedicated clinical pharmaconomists. The observers followed a protocol to ensure reliable and valid observations. They were instructed to intervene only if they observed a severe error during the administration process. A 1-day pilot data collection was used to train the observers, to test the protocol, and to align the process to the definition of errors to reduce interobserver variability.

All observations were recorded on paper-based forms and entered into an Excel spreadsheet (Microsoft Office 2003). These were subsequently compared with the prescribed medication in the eMAR and the written procedures, and any discrepancies were considered errors and categorized as outlined in Table 1.

The number of avoided medication administration, procedural, and clinical errors was calculated in relation to the average number of patient-days multiplied by the average number of doses per patient every 24 hours. Data on patient-days were extracted from the hospital's administrative database and the number of medications was collected from the direct observation study. Table 2 presents background information of the participating wards.

The costs of errors estimated from ADEs, patients needing additional treatment, increased length of stay, and so forth were not assessed because this was considered beyond the scope and feasibility of this study.

Economic evaluation

The economic evaluation consisted of a cost analysis and a cost-effectiveness analysis with a 6-month time horizon. The analyses compared the AMS with the conventional medicine delivery in which medicines were delivered in original packaging and dispensed by nurses in the medication room at the ward.

The cost analysis used the hospital perspective and a short-term incremental costing approach on the basis of the assumption that only the costs related to medicine delivery and handling would change.

The cost model was devised to identify the incremental costs related to the AMS compared with conventional delivery. Common costs for both methods, such as the costs of medicines outside the AMS assortment, were not recorded. The medicine delivery procedures were assumed to have no influence on overhead costs including hospital administration, cleaning, and rent. The costs of medicines were not expected to change as a result of the intervention and were disregarded. Costs of planning, developing, and implementing the intervention were calculated and presented separately as implementation costs.

We used microlevel costing to obtain accurately estimated unit costs for individual items and services. Field studies were conducted to identify relevant key items related to cost activities as well as costs that varied with and without the AMS. Subsequently, on-site data collections were designed to collect data on resource use and to obtain unit costs.