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Closed-loop medication management systems

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Closed-loop medication management systems

Policy question

Do closed-loop medication management systems reduce dispensing and medication administration errors and improve efficiency?

Current evidence shows

To date there have been relatively few comprehensive evaluations of closed-loop medication systems and their effects. Available study findings suggest closed-loop medication management systems have the potential to reduce dispensing and medication administration errors, though the impact across error types may not be uniform. There is also some evidence that closed-loop systems may facilitate reduced medication turnaround time and may facilitate a reduction in the time taken to administer a medication. However, existing studies are highly specific to individual systems evaluated.

Background

The medication management cycle is a complex process involving the decision to prescribe a medication, dispensing and storing the medication, administering the medication, and monitoring for a response.[1] This process can be considered a 'closed-loop' when feedback from each step informs the continuation of the process and the start of a new cycle.[2] In a hospital-based closed-loop medication management system (CLMMS), each of the steps in the medication management cycle are automated, including verifications for essential elements such as the Six Rights of medication administration and the accurate documentation of information necessary for the continuation of the process. To close the loop, the CLMMS comprises a fully linked system with electronic prescribing, technology for the automation of dispensing and/or stock control, and automated dispensing cabinets or barcoded unit-doses with a linked electronic medication administration record. Some CLMMS also include automated administration of certain medications such as anaesthesia,[3] or treatments such as oxygen,[4] via control systems that monitor patient variables.

The individual components of a CLMMS, including electronic prescribing systems,[5,6] automated dispensing systems,[7-9] barcoded medication administration,[10,11] and electronic medication administration records,[12,13] have each been evaluated independently. CLMMS, which comprise and link all these components, are comparatively expensive and require significant changes in medication processes, including managing unit dose barcoding, and are not yet widely implemented in Australia.[14] As a result, there is scant evidence describing their impact on medication error rates or efficiency. In 2019, The Society of Hospital Pharmacists of Australia highlighted some of these issues, concluding that CLMMS with unit dose barcoding are currently not a sustainable solution for most Australian hospitals.[15]

Methods

A literature search was undertaken to identify studies relating to CLMMS in the hospital setting. Searches were performed in PubMed, Embase, and CINAHL. Google Scholar was used to identify grey literature. Conference abstracts, review articles, duplicates, commentaries and letters as well as articles describing implementation of CLMMS (e.g. guidelines for successful implementation or studies limited to post implementation error rates) were excluded. The search was limited to English language articles published after 1980 and was run in May 2021. Studies were included if they reported on the impact of CLMMS on medication error rates or medication process efficiency. Articles with outcomes that were specific to a particular medication or patient condition were excluded. Articles collecting data solely through voluntary reporting were excluded due to known issues of under-reporting.[16] Included articles described the use of CLMMS, defined as a complete and fully linked system with electronic prescribing, automated dispensing systems, and electronic medication administration records. The descriptions of CLMMS as stated in the studies are provided in Table 1.

Results

The search yielded 1748 potentially relevant published studies. Twelve articles met inclusion criteria, three of which were conducted in the US,[17-19] two were conducted in Denmark,[20,21] two from the UK,[22,23] and one each from France,[24] Switzerland,[25] Singapore,[26] South Korea,[27] and Australia.[28] Outcome indicators reported included medication administration error (MAE) rates, dispensing error rates, and time taken to complete medication-related tasks.

Medication administration errors

Seven studies assessed the impact of CLMMS on the rate of MAEs,[17-22,25] and an additional two studies were limited to reporting post-implementation MAE rates. [26,27] Only two studies had controls.[20,21] Eight studies used prospective observations of medication administration, and one study collected data counting CLMMS automated error alert notifications.[27] Six of the seven studies assessing the impact of CLMMS reported a statistically significant reduction in MAE rates.[17,18,20-22,25] The only study not reporting a significant reduction in MAE rates was conducted in a US paediatric intensive care unit (PICU) where medication infusions using a bedside infusion pump were observed.[19] In that PICU, smart infusion pumps were linked with an electronic prescribing system, and later an automated pharmacy system was incorporated to 'close the loop'. Although a reduction in MAEs was noted, this reduction was not statistically significant.

Of the six studies reporting a statistically significant reduction in MAE rates, three compared CLMMS with paper-based medication systems,[20-22] and three compared an existing system with electronic prescribing, medication administration and automated dispensing with the later addition of integrated barcoding technology.[17,18,25] The results from these studies are provided below.

CLMMS vs. paper-based medication management

The first study collected data three to six months before, and six to twelve months after, the CLMMS intervention was implemented.[22] This UK study reported that 7.0% of 1473 non-intravenous administrations had at least one MAE and this reduced to 4.3% of 1139 administrations after the system was implemented. Two further studies were conducted in two Danish acute medical units (one with CLMMS and the other without).[20,21] The first study reported on data collected during three weeks before, and four months after CLMMS implementation,[20] and the second study, conducted in the same setting, included a longer term follow-up at ten months.[21] Compared to the medical unit without CLMMS, the overall administration error rate was reduced by 57% in the unit with CLMMS at four months,[20] and 47% at ten months.[21] Sensitivity analysis showed a lack of consistency in the types of administration errors that were reduced by the CLMMS as compared to changes observed in the control unit. The CLMMS was associated with a significant reduction in MAEs where the patient did not receive the medication as prescribed (including wrong drug, dose, or patient), in the initial follow-up. Deviations from written hospital procedures or guidelines (including wrong strength or timing errors, poor documentation, not checking prescriptions or using the barcode scanning) did not change significantly. At the ten-month follow-up, the reverse was true. The authors attributed this inconsistency to variations in the error rates observed in the control ward which were unexpectedly low at baseline followed by an initial decrease and later increase.

CLMMS vs. electronic medication management

Three studies reported on the integration of medication barcoding technology to an existing system with electronic prescribing, medication administration and automated dispensing.[17,18,25] The first study was conducted in Switzerland and reported a reduction in error rates from 9.9% of doses six months before, to 4.5% three months after the intervention was integrated.[25] Further analysis showed that wrong medication, dose, patient and form errors were significantly reduced, while reductions in the rates of errors of omission, and preparation without an order did not change significantly.

Two additional studies were conducted in the US.[17,18] The first found an 11.5% error rate (776 of 6723 administrations contained errors) on wards without integrated barcoding technology and 6.8% on wards with this integration (495 of 7318 administrations were in error).[18] Further analysis showed a reduction in all error types, with the greatest difference observed for administration documentation errors. Finally, a second US study reported on administrations in medical and intensive care units separately before and after the integration of barcoding technology.[17] This study found a significant reduction in medication administration errors on the medical units (8% or 71 of 888 administrations with errors reduced to 3.4% or 24 of 697 administrations with errors). A significant reduction was not observed on the intensive care units (11.0% or 41 of 374 administrations with errors reduced to 9.9% or 39 of 394 administrations). This difference

between units was attributed to a significant decrease in wrong timing and omission errors post integration on the medical units while these types of error were infrequent in the intensive care units.[17]

Post-CLMMS implementation MAE rates

Two studies were limited to descriptions of post-implementation MAE rates.[26,27] The first reported that 400 of 5502 observed opportunities for error resulted in an MAE, resulting in a MAE rate of 7.3% (95% CI 6.6–8.0%).[26] The second study reported that a total of 35082 MAE alerts occurred from 2,874,539 administrations, resulting in a MAE rate of 1.2%.[27] In comparison, administration error rates in hospitals without CLMMS have been reported to range between 8.6 and 28.3% of opportunities for error, with a median error rate of 19.6%.[29]

Medication dispensing errors

No study assessed the impact of replacing a hospital paper-based medication system with a CLMMS on dispensing errors. However, one study reported the impact of CLMMS on the rate of dispensing errors following a system upgrade in a hospital using an existing electronic prescribing system and automated dispensing system.[24] The hospital introduced an integrated barcoding medication administration system, which the study authors considered to close the medication loop, though there was no information return regarding medication administration to the electronic prescribing system. Data were collected from an intervention ward that was operating with the CLMMS and compared with three other wards without the addition of the linked barcoding medication administration system. There was no significant change in the overall dispensing error rate which was 7.9% of the assessed opportunities for error in both the intervention and control wards (59 of 750, and 53 of 674, respectively). However, there was a change in the types of dispensing errors recorded. That is, the dose omission error rate was significantly higher in the intervention ward and attributed to failures in the interoperability of systems. Rates of wrong patient and unordered-drug errors were significantly lower on the intervention ward compared to the control wards.

Timeliness and workflow efficiency of medication administration

Three studies assessed the impact of CLMMS on workflow. All collected data on the time taken to complete medication-related tasks.[22,25,28] The first assessed the time taken to prescribe, dispense and administer 32 medications using paper-charts three to six months before, and 15 medications six to twelve months after the system was implemented.[22] A change in staff time was observed such that prescribing was on average 24 (95% CI: 3 – 45) seconds faster than at baseline. There was an increase in pharmacist time, as prior to the CLMMS only 78% of medication orders were accessible for review and post implementation all orders were accessible and required review. Drug rounds were faster, allowing nursing staff to increase the proportion of their total time spent on medication-related tasks outside of drug rounds by 7.6% (95% CI: 2.4 – 12.8%). The second study was conducted in Australia over two weeks in a private hospital with CLMMS and two other private hospitals without CLMMS.[28] The study measured the time taken to administer a newly prescribed medication from when it was scheduled to be administered – the 'medication turnaround time'. The CLMMS-equipped hospital had a shorter median turnaround time of 35 minutes (interquartile range of 8-57 minutes) compared to the paper-based hospitals' median of 120 minutes (interquartile range of 30-180 minutes). This difference equated to a 71% faster average time to first dose. Finally, one study conducted in Switzerland observed the time taken to prepare a single-medication dose, with 35 doses observed before, and 44 doses after a medication barcoding system was integrated into an existing system with electronic prescribing and automated dispensing with electronic medication administration records.[25] The mean time taken decreased significantly from 24.3 seconds to 15.1 seconds.

CLMMS workarounds, safety risks and contributing factors

The effectiveness of all new health information technologies may be hindered by workarounds that occur when staff override or circumvent technology due to a poor fit between workflow and the technology.[30] Three studies, all using direct observation, examined workarounds or system issues associated with the use of CLMMS.[23,24,26] The first study reported that errors were most frequently caused by the inappropriate use of the system, such as when leaving the system logged in and unattended, and by system functionality problems such as when some medications were not able to be scanned.[26] System functionality problems were reported to lead to unintended procedures in the use of the system and was subsequently the most frequent cause of medication administration errors. The second study noted a decline in doctors' sensemaking and situational awareness and nurses' thinking and productivity when certain tasks became automated.[23] The third study reported that 37.7% of all medication errors (n=20

Table 1. Studies evaluating closed-loop medication systems

Study	Electronic prescribing system	Automated drug dispensing system	Barcoding/unit-dose	Electronic medication administration record
Austin, 2018[28]	NR	Profiled ADC	Unit dose BCMA	NR
Berdot, 2019[24]	DxCare, Medasys	ADC (Omnicell Inc.)	Unit dose	NR
Foo, 2017[26]	NR	Inpatient Pharmacy Automated System	Unit dose satellite pharmacy, BCMA	NR
Franklin, 2007[22]	NR	Ward-based automated dispensing	Barcode patient identification	ServeRx V.1:13: MDG Medical, Israel
Furniss, 2020[23]	Drug library	NR	Smart pumps	NR
Hwang, 2016[27]	NR	Automated tablet dispensing and packaging system	Radio-frequency identification, barcodes, and hand-held point-of-care devices	NR
Küng, 2021[25]	WIEGAND MedManager®	NR	Unit dose BCMA	NR
Risør, 2016[20]	NR	Automated drug dispensing	BCMA	NR
Risør, 2018[21]	NR	Complex automated medication system	BCMA then non-patient-specific automated system	NR
Russell, 2015[19]	NR	Pharmacy systems	Smart pumps	NR
Poon, 2010[18]	NR	NR	BCMA	NR
Helmons, 2009[17]	CPOE was bidirectionally interfaced with the pharmacy information system	Unit-based automated dispensing cabinets	BCMA	NR

CPOE: Computerised Provider Order Entry; ADC: Automated Dispensing Cabinet; BCMA: Barcode-assisted Medication Administration; NR: Details of this component were not reported.

of 53) were due to the use of the system, or health information technology (HIT) errors. The most frequent type of HIT-related error was an omission error where interoperability problems prevented orders being communicated between the electronic prescription and a patient's electronic medication administration record.[24]

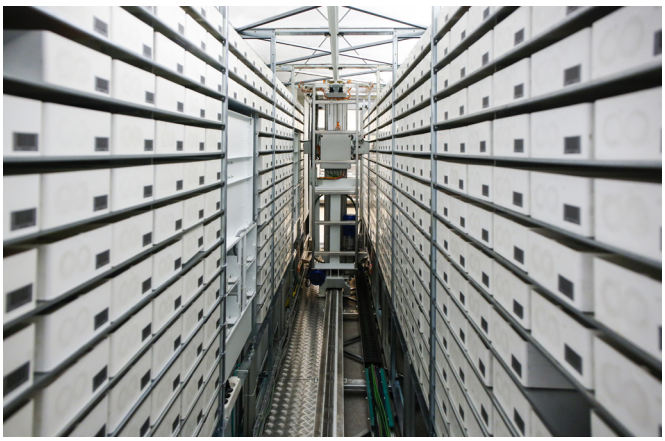
Conclusion

The results from these early studies evaluating this relatively new and complex intervention consisting of integrated electronic prescribing, automated dispensing, barcoded medication administration, and electronic medication administration records are promising. All four studies assessing medication administration error rates, and one study assessing dispensing error rates, found a significant reduction in errors when comparing CLMMS with paper-based

settings or wards with individual technologies such as electronic prescribing and medication administration records. Similarly, three studies measuring the impact of CLMMS on workflow efficiency, measured as time taken to administer medications, showed significant improvements with full system implementation. However, there is an absence of studies with rigorous designs with controls and thus the evidence base is weak. Furthermore, the cost-effectiveness of these expensive and complex systems is yet to be determined. Lastly, as there are significant differences in the systems that have been evaluated, the generalisability of results from the limited studies is unclear.

Lessons learned from implementation

- Implementing a CLMMS requires significant testing prior to going live, particularly to ensure seamless integration between the individual system components. Difficulties may occur in communication between information technology professionals with a technical approach and clinical staff with a medical approach to the system.[31]
- The Society of Hospital Pharmacists of Australia recently highlighted the need for consistent manufacturer barcoding on medications available in Australia, and the need for regulatory support from the Therapeutic Goods Administration in this regard. In the absence of these elements, closing the medication loop, particularly with unit dose barcoding systems, is not a feasible solution for most Australian hospitals.[15]



Automated medication system (photograph: Roman, Adobe Stock)

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