Title Page

Impact of In-Station Medication Automated Dispensing Systems On Prehospital Pain Medication Administration

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ABSTRACT

Introduction: Medication automatic dispensing systems (ADS) have been implemented in many settings, including fire-based EMS stations. The aim of this study was to evaluate the impact of in-station ADSs on controlled substance administration rates and EMS response intervals.

Methods: This study was a retrospective review of data from a single fire-based EMS agency. Medication administration rates and EMS response intervals were compared before ADS implementation (P1; 6/1/15 to 5/31/16) and after ADS implementation (P3; 6/1/17-5/31/19). Cases with missing data and during a one-year implementation period were excluded.

Results: 4045 cases were identified in P1 and 8168 in P3. The odds of morphine or versed administration increased following ADS implementation: OR = 1.77 (95% CI: 1.53, 2.03) and OR = 1.53 (95%CI: 1.18, 2.00) respectively. There were statistically, but likely not operationally significant increases in median response interval and transport interval from P1 to P3 of 14 seconds, ($p < 0.001$) and 39 seconds ($p< 0.001$) respectively. Time at hospital for all calls decreased by more than 11 minutes for all transports, from a median of 34 minutes (IQR; 23.7, 45.5) to 22.7 minutes (IQR:18.5, 27.6) in P3, $p < 0.001$ and by 27.9 minutes for calls in which a controlled substance was given: P1 = 50.6 minutes (IQR: 34.6, 63.2), P3 = 22.7 minutes (IQR: 18.3, 27.4), $p < 0.001$.

Conclusion: In this system, medication ADS implementation was associated with an increase in the rates of controlled substance administration and a decrease in the time units were at hospitals.

INTRODUCTION:

Paramedics utilize critical decision-making skills when providing emergency medical care. Using these skills, paramedics must make risk vs benefit decisions to administer advanced life support (ALS) medications, including pain medications[1,2]. Multiple factors might influence the decision to administer a pain medication immediately or to delay medication administration until arrival at an emergency department (ED)[3,4]. Some of these factors might include patient presentation, response, the prehospital environment, and the need to optimize EMS system operations. One operational factor that must be considered is how medication administration affects EMS out of service time. In many EMS systems the need to replace medications at a hospital pharmacy, particularly pain medications, can increase an agency's out-of-service time and has the potential to decrease ALS medication administration[4]. In-station medication dispensing systems or in-station Automated Dispensing Systems (ADS) may reduce or eliminate this operational barrier to medication administration.

Many authors have reported on the need for paramedics to both assess patients' pain and provide prehospital treatment of pain[2,5-8]. Previous studies have surveyed paramedics to identify factors that influence their decisions to administer pain medications in the prehospital setting[4]. However, these studies are limited by self-reporting and recall bias. In this study we investigate the impact of an operational change that eliminated the need for paramedics to replace narcotics at hospital pharmacies and allowed replacement of these medication at their station. This change was made with the goal of reducing EMS out-of-service times (the time from EMS resource dispatch to EMS resource return to service). Our hypothesis was that implementation of an in-station controlled substance replacement program would both reduce out of service times and increase pain medication administration.

To evaluate this hypothesis, the primary aim of this study was to measure changes in narcotic utilization before and after an in-station narcotic replacement system was implemented. As a secondary aim, we evaluate the impact of this change on both EMS out of service times and the administration of other medications.

METHODS:

Study Design:

This study was a retrospective review of data collected as part of a quality improvement project conducted by a single EMS agency. Data was available from June 1, 2015 to May 31, 2019 and included EMS system performance measures, limited patient demographics (age, gender) and which, if any, ALS medications were administered. To evaluate the impact of implementing the in-station narcotic replacement program three study periods were identified: P1, before in-station narcotic replacement was available, June 1, 2015 through May 31, 2016; P2, exclusion period, during implementation of the in-station narcotic replacement system, June 1, 2016, through May 31, 2017; P3, after the in-station narcotic replacement program was in place, June 1, 2017, through May 31, 2019. No analyses were performed on cases in P2. Duplicate cases, cases without complete EMS response times, and cases identified during P2 were excluded. Outcomes were then compared between P1 and P3.

Study Population and Setting:

A single fire-based EMS agency, Northwest Fire District (NWFD), provided quality improvement data for this study. NWFD is located in Southern Arizona and provides 911 Advanced Life Support (ALS) first response and ALS transport services. From July 2016 through May 2017 the agency placed 5 ADSs (UCapIt, Intelligent Dispensing Solutions, Clive, IA 50325) in strategically located fire stations allowing for medication replacement in 50% of the NWFD stations. During P1, prior to ADS implementation, ALS medications were replaced in hospital emergency departments at the time of transition of patient care. The one exception to this practice was the replacement of Morphine, which required the paramedic to go to the hospital pharmacy. Following implementation of the ADS, par levels (the number of doses carried in a single paramedic drug box) were increased such that units could remain in service

after delivering a patient to the ED and re-stock any used medications at their station or by stopping at a station with an ADS on the way back to more distant stations.

Throughout all study periods morphine was the only narcotic pain medication available to paramedics. Non-Narcotic controlled substances included Midazolam and Ketamine. Ketamine was introduced during P2 and paramedics were allowed to administer low dose ketamine for those patients with an allergy to morphine or those patients who did not have good control of their pain after their first dose of morphine.

Human Subjects Committee Review:

This study was reviewed and approved by the University of Arizona IRB as a retrospective review of data collected for the purpose of quality improvement.

Measurements and Key Outcomes:

The primary outcome was the number of patients given controlled medications (morphine, ketamine and midazolam). Secondary outcomes were commonly reported EMS response intervals:

- Out of Service Time; Time from ALS unit dispatch to ALS unit return to service.
- On Scene Time; Time from ALS unit arrival on scene to departure from scene.
- At Hospital Time; Time from ALS unit arrival at hospital to departure from hospital.

Simple descriptive statistics were used to describe the results and compare P1 to P3. This included the number of patients and percent of total ALS responses that received pain medications. Outcomes were compared using odds ratios (ORs) with 95% Confidence Intervals (95% CI). EMS system performance measures are reported as the median response time in seconds and differences were evaluated using Kruskal-Wallis test. Response time data was then compared graphically using box-plots and histograms to better illustrate the observed changes.

Statistical analyses and data visualization were performed in R 4.0.4 with the ggplot2 package[9,10].

RESULTS:

As illustrated in Figure 1, after excluding cases with missing data, there were 4045 cases (337 per month) in P1 and 8168 cases (340 per month) in P3. Limited demographic data was available given the retrospective nature of this study. The median age in P1 was 66 years (IQR: 42, 81) while the median age in P3 was 60 years (IQR: 40, 76). After excluding 4 cases in each group that were missing gender data, 40.1% in P1 were identified as male while in P3, 40.5% were identified male.

The results of the primary analysis, administration of controlled substances, is illustrated in Table 1. Despite the introduction of an alternative pain medication during P2 (ketamine), a significant increase was observed in the rate of morphine administration following implementation of the ADS. Prior to the in-station medication dispensing program 6% patients transported by an ALS resource received morphine, while after implementation more than 10% received morphine, with the odds of morphine administration increasing after ADS implementation; OR = 1.77 (95% CI: 1.53, 2.03). Similarly, more patients were given midazolam (OR = 1.53; 95% CI: 1.18, 2.00) following implementation of the ADS. Patients given any controlled substance increased dramatically, with 7.9% given controlled substances in P1 and 14.4% receiving controlled substances in P3. The odds of a patient transported to the hospital, by ALS providers, receiving any controlled substance was nearly twice as high following ADS implementation (OR 1.97, 95% CI: 1.73, 2.24)

For all call types and transports, analysis of the secondary outcomes identified a change in EMS response intervals over the same time frame before and after implementation of the ADS, as illustrated in Table 2. For all calls, although statistically significant, the change in the median response interval (dispatch to arrive at scene) was effectively unchanged from P1 (4.9 minutes; IQR: 3.8-6.4 minutes) to P3 (5.1 minutes; IQR: 4.0-7.0 minutes), $p < 0.001$ with an increased in the median response time of 14 seconds. Similarly, median transport time (time

from depart scene to arrival at hospital), although statistically different, was similar between P1 and P3 with a median decrease the transport time of 39 seconds between P1 and P3, < 0.001. As illustrated in Figure 2a, the time at hospital (time from arrival at hospital to back in service) for all calls decreased by more than 11 minutes in P3 from a median of 34 minutes (IQR: 23.7, 45.5) to 22.7 minutes (IQR:18.5, 27.6) in P3, $p < 0.001$.

Evaluation of those response intervals for cases in which a controlled substances were administered is illustrated in Figure 2b. Among those cases with controlled substance administration the change in response time was greatest among those transports in which morphine was given which had a median at hospital time of 50.6 (IQR: 34.6, 63.2) before ADS implementation and 22.7 (IQR: 18.3, 27.4) after, $p < 0.001$.

DISCUSSION

Overall, in this retrospective, observational, single agency study we observed an association between implementation of an ADS and both an increase in controlled substance utilization rates and a decrease in the time EMS providers spent at the hospitals after administration of a controlled substance. These changes were substantial with ADS implementation associated with more than a 75% increase in the rate of morphine administration and more than a 50% increase in the rate of midazolam administration.

There are several possible reasons that controlled substance administration rates increased. Prior to ADS implementation, there were many administrative obstacles to controlled substance replacement, many of which were removed. This included elimination of the requirement that paramedics have hospital staff (generally a nurse) sign for medication administration, complete a patient care report prior to medication replacement, print that report and show the report to the pharmacy as proof of medication administration. Perhaps most importantly, paramedics no longer needed to wait for the pharmacy staff to verify the documentation and provide a replacement dose of the controlled substance.

Informal conversations with field providers confirmed that some of these factors were likely to account for the observed increased in medication administration following ADS

implementation. One anecdotal experience suggested that in part paramedics feared that hospital staff would not agree with their reason for pain medication administration and it would be difficult to replace the medication. Similarly, other paramedics stated, “we are so close, we just wait for medications to be given in the hospital, it’s easier.”

The primary concern voiced by paramedics was the additional time required to get medications replaced at the hospital. As part of this review, we did evaluate the time that EMS units were out of service at the hospital. By implementing an ADS, paramedic time at the hospital was significantly reduced:11-minute reduction in at hospital times for all ALS transports, 27-minute reduction in the at hospital times for cases in which morphine was given, and a 22-minute reduction in at hospital times for cases in which midazolam was given. It is likely that that these two findings are related, ADS implementation reduced a barrier to controlled substance administration (replacement at a hospital pharmacy) and as such the willingness of paramedics to administer these medications.

In the EMS system studied, the ADS systems were implemented with the goal of improving inventory control by reducing waste and preventing shortages. The ability of the ADS to safely store and dispense controlled substance provided a convenient additional advantage to the system. Obviously, to implement an in station-controlled substance program it was critical to ensure that proper security measures were in place to prevent individuals from diverting the substances. As with many medication ADSs, the ADS used in this EMS system met all DEA storge requirements and the EMS agency ensured that the ADS was in a secure locked area. Additional security measures were implemented by the EMS agency and agency medical director including independent ordering and restocking as well as an audit system to ensure any errors were identified early and corrected, while any potential diversion was identified and reported as required under federal and state rule.

It does not escape us that the goal of this program was to increase opiate administration rates during a time when many are suffering from the raging opiate epidemic. However, we strongly believe that in the prehospital setting, treatment of pain, which includes the administration of pain medications, should be a primary goal of patient care. A single dose of

morphine is unlikely to cause addiction and appropriately treating pain for those with acute pain is of value to our community.

LIMITATIONS

This study has many limitations. As a retrospective review of data collected for quality improvement this study utilized a limited data set and as a result there is almost certainly unmeasured confounders. Without detailed demographic and EMS provider data we can only make statements of association in this single EMS system and the findings are not intended to be generalizable. It is possible, that underlying changes in patient demographics or illness/injury patters occurred between P1 and impacted these findings, for example: there was a significant difference in median age between P1 and P3, the median age in P3 was 6 years younger than that in P1, this could have resulted in fewer patients being given pain medication in P1 due to their more advanced age. Similarly, we were not able to obtain data on paramedic primary impression, it is possible that traumatic injury was more common in P3 than P1 resulting in increased pain medication admiration rates. Finally, prehospital providers were aware that one potential advantage of the in-station narcotic program was the removal of barriers to administration of controlled substances. This could have led to conscious or unconscious bias resulting in paramedics clearing hospitals quicker than they had before or believing that leadership teams wanted more patients to receive controlled substance.

Coincidentally, the implementation of the in-station ADS overlapped with the implementation of a new pain management patient care guideline which included ketamine as an alternative pain medication. This could have increased the number of patients given morphine by increasing paramedic awareness of the need to treat pain. However, it is more likely that morphine administration would decrease with this change as paramedics had alternatives to morphine for pain control following this change.

As a retrospective study, there were several questions that arose with review of this data that unfortunately, cannot be answered. As we were unable to ask paramedics at the time of patient care why they chose to give the medication or not, we cannot be sure why controlled substances were or were not given. Furthermore, the EMS agency studied underwent an ePCR

vendor change during the study period and as a result it was not possible to obtain data such as pain scores or patient primary impressions in a standardized format that would allow comparison between systems.

CONCLUSION:

In this single system study, implementation of a program allowing in-station replacement of all controlled substances was associated with a significant increase in the rates of controlled substance administration and a decrease in the time units were at receiving hospitals. This change resulted in improved operational efficiency by decreasing overall EMS unit out of service time.

Figures and Tables:

Figure 1: Identification of Cases

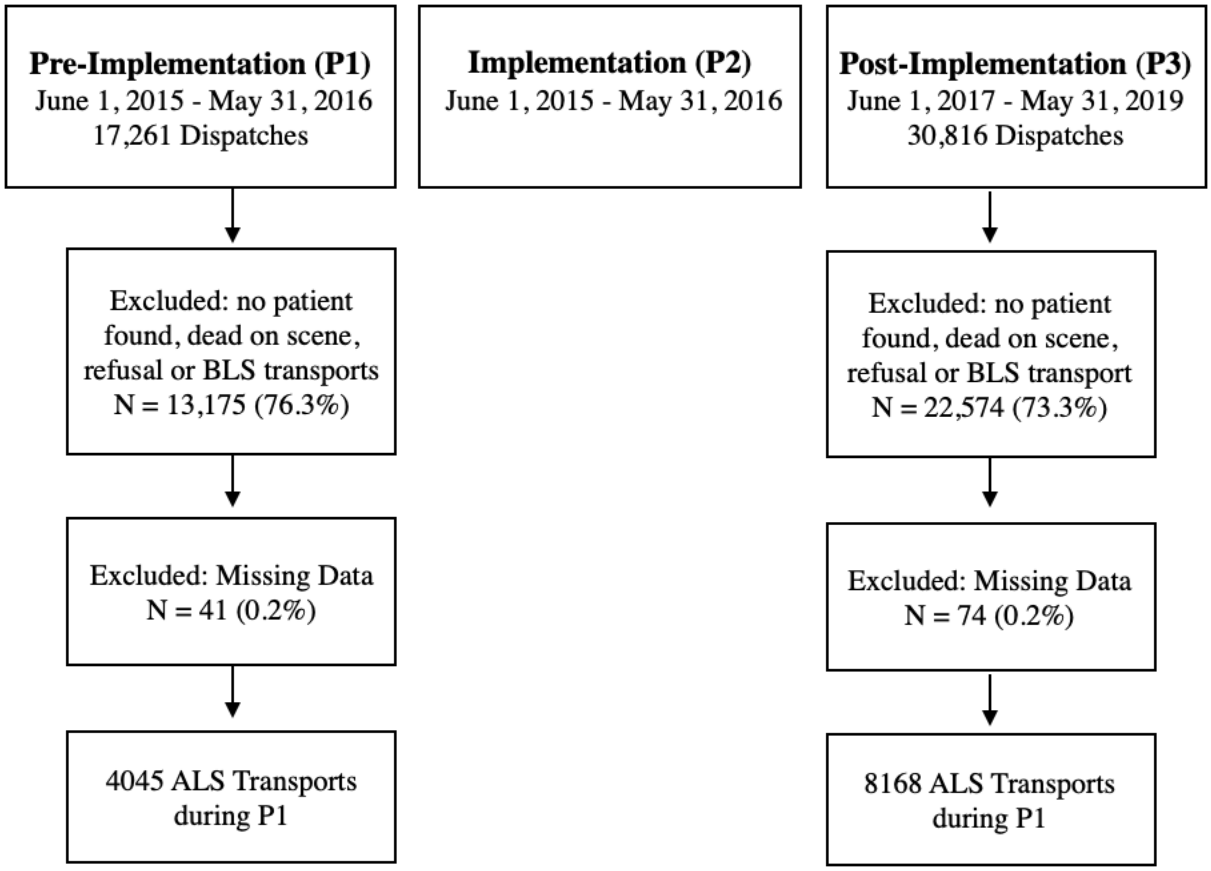


Table 1: Administration of ALS Medications before and after implementation of an in-station Automated Medication Dispensing (AMD) Machine.

	P1 (N, %)	**P3** (N, %)	**OR (95% CI)**	**p-value**
ALS Transports	4045 (11.08 per day)	8168 (11.19 per day)	-	-
Patients Given Morphine	243 (6.01%)	831 (10.17%)	1.77 (1.53, 2.03)	p < 0.001
Patients Given Ketamine	1 (0.02%)	117 (1.43%)	-	-
Patients Given Versed	75 (1.85%)	230 (2.82%)	1.53 (1.18, 2.00)	p = 0.015

Table 2 : EMS Response Intervals

	P1 (Time in minutes, IQR)	**P3** (Time in minutes, IQR)	**p-value**
Response Interval	4.9 (3.8, 6.4)	5.1 (4.0, 7.0)	< 0.001
Transport Interval	10.2 (6.0, 17.0)	9.5 (5.7, 16.4)	< 0.001
At Hospital Interval			
All transports	34.0 (23.7, 45.5)	22.7 (18.5, 27.6)	< 0.001
Morphine	50.6 (34.6, 63.2)	22.7 (18.3, 27.4)	< 0.001
Versed	45.7 (29.5, 61.1)	23.1 (18.6, 27.5)	< 0.001
Ketamine	N/A	24.7 (19.7, 30.6)	N/A

Figure 2: Time at hospitals before in-station medication replacement systems (P1) and after in-station medication replacement systems (P3) were Implemented

Figure 2a

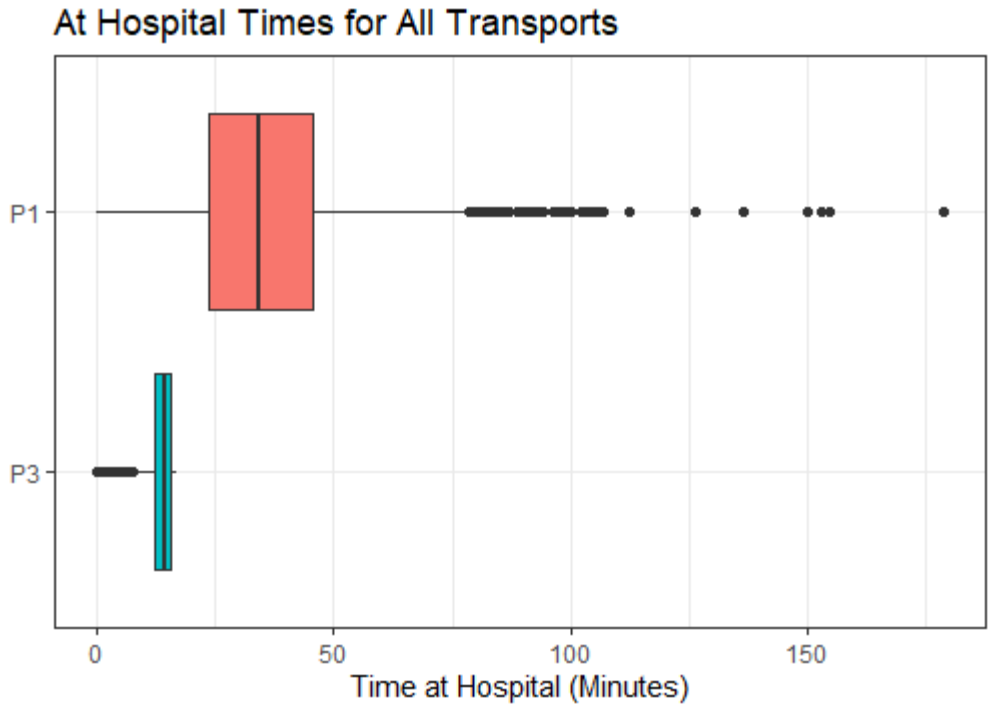
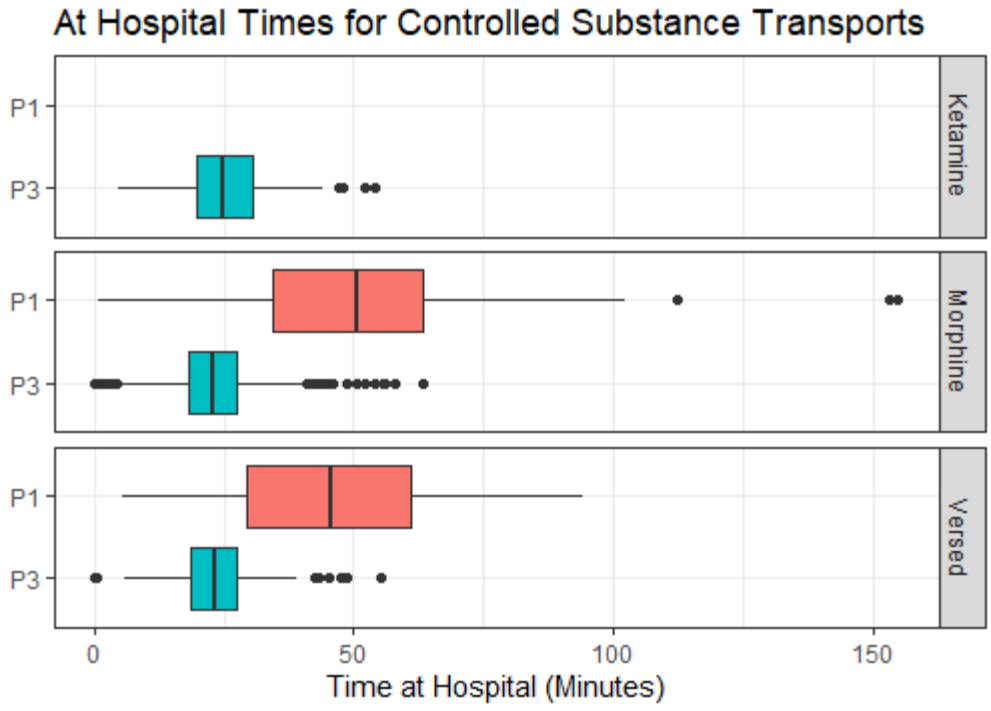


Figure 2b



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