BRIEF REPORT

Medication Administration in Critical Care Transport of Adult Patients with Hypoxemic Respiratory Failure

Susan R. Wilcox, MD;[1,2] Mark S. Saia, BS, RRT, NRP, FP-C;[2] Heather Waden, RN, MSN, CCNS, CCRN, CFRN, CEN, EMT;[2] Susan J. McGahn, MSN, CCRN, CEN, EMT;[2] Michael Frakes, APRN, CCNS, CFRN, CCRN, EMTP;[2] Suzanne K. Wedel, MD;[2] Jeremy B. Richards, MD[3]

1. Department of Emergency Medicine, Massachusetts General Hospital, Boston, Massachusetts USA
2. Boston MedFlight, Bedford, Massachusetts USA
3. Division of Pulmonary, Critical Care and Sleep Medicine, Department of Internal Medicine, Beth Israel Deaconess Medical Center, Boston, Massachusetts USA

Correspondence:
Susan R. Wilcox, MD
55 Fruit Street
Boston, Massachusetts 02114 USA
E-mail: susanrwilcoxmd@gmail.com

Conflicts of interest: This study was supported by institutional funds without external grant support. The authors have no conflicts of interest to report.

Keywords: intravenous infusions; medication systems; pumps, infusion; transportation of patients

Abbreviations:
CCT: critical care transport
IRBs: Internal Review Boards
IV: intravenous

Received: March 28, 2015
Revised: May 28, 2015
Accepted: June 6, 2015

doi:10.1017/S1049023X1500494X

Online publication: July 16, 2015

Abstract

Introduction: Critical care transport (CCT) teams must manage a wide array of medications before and during transport. Appreciating the medications required for transport impacts formulary development as well as staff education and training.

Problem: As there are few data describing the patterns of medication administration, this study quantifies medication administrations and patterns in a series of adult CCTs.

Methods: This was a retrospective review of medication administration during CCTs of patients with severe hypoxemic respiratory failure from October 2009 through December 2012 from referring hospitals to three tertiary care hospitals.

Results: Two hundred thirty-nine charts were identified for review. Medications were administered by the CCT team to 98.7% of these patients, with only three patients not receiving any medications from the team. Fifty-nine medications were administered in total with 996 instances of administration. Fifteen drugs were each administered to only one patient. The mean number of medications per patient was 4.2 (SD = 1.8) with a mean of 1.9 (SD = 1.1) drug infusions per patient.

Conclusions: These results demonstrate that, even within a relatively homogeneous population of patients transferred with hypoxemic respiratory failure, a wide range of medications were administered. The CCT teams frequently initiated, titrated, and discontinued continuous infusions, in addition to providing numerous doses of bolused medications.

Wilcox SR, Saia MS, Waden H, McGahn SJ, Frakes M, Wedel SK, Richards JB. Medication administration in critical care transport of adult patients with hypoxemic respiratory failure. *Prehosp Disaster Med*. **2015;30(4):431-435.**

Introduction

In the United States, critical care transport (CCT) teams are comprised typically of highly trained nurses and paramedics who provide airway management, advanced ventilator support, invasive monitoring, and other intensive care procedures.[1,2] These teams frequently are called upon to provide interfacility transport of patients, either by air or ground, with a goal of providing care during transport that is commensurate with that provided in the intensive care unit.

There are few published data on the patterns of medication administration by CCT teams.[2,3] Given the wide range of patients transported, CCT teams must initiate, titrate, and discontinue a vast array of medications. Patients on mechanical ventilation particularly are at high risk of adverse events when being transported between facilities, requiring significant personnel and resource utilization during transport.[4-6] Understanding the number and frequency of medications administered to this subset of critically ill patients with hypoxemic respiratory has implications for formulary development, crew training, and patients' inter-transport needs. This study describes the medication administration patterns for a subset of patients with severe hypoxemic respiratory failure transported by one CCT service.

Materials and Methods

This study was approved by the Internal Review Boards (IRBs) of the three receiving hospitals, with the IRBs waiving the need for informed consent.

This was a retrospective review of transports of patients with severe hypoxemic respiratory failure from October 2009 through December 2012 from referring hospitals to three tertiary care hospitals. The CCT service was a consortium of six academic medical centers, with approximately 2,700 transports a year, of which, approximately 85% were inter-facility. Each fully integrated team consisted of one Registered Nurse and one Emergency Medical Technician-Paramedic per duty shift for each rotor wing, fixed wing, and ground vehicle, and each team completed the full range of transport requests.

All decisions to transfer a patient were initiated by the physicians at sending facilities. The CCT service electronic medical record system was searched to identify intubated, adult patients with a primary clinical classification, as indicated by the original transport team, of "medical" or "respiratory," excluding transports with a primary clinical classification of neurological, trauma, burn, surgical, or cardiac. From that initial screening, 2,251 records were filtered by the primary and secondary ICD-9 codes to identify patients with pulmonary or septic diagnoses. Transport records were searched electronically by three of the co-authors for the terms "Acute Respiratory Distress Syndrome," "hypoxia," or "hypoxemia," and the charts of patients receiving at least a fraction of inspired oxygen of 50% were selected for inclusion. Documentation of medication administration was assessed in both the medication administration flowsheet and the narrative summary by three of the co-authors and transcribed into a primary database, maintained at the primary research site. Data were collected inclusively, and a medication was documented as having been administered if it was recorded in either the narrative summary or in the flowsheet. While documentation practices and the thoroughness of the transport records indicate no obvious omissions, if medications were administered but not recorded in the transport record, there were no ancillary data sources to assess and any missing data were therefore excluded from analyses.

The transport records were reviewed for demographic data, pertinent comorbidities, and information regarding diagnosis, as known to the CCT team, and were recorded. All medications administered on the included transports were recorded, and the doses for both bolus dosing and infusions were recorded. Administration of crystalloid boluses and transfusion of blood products were also recorded. An "administration" of medication was defined as one patient receiving one medication via one route, even if the patient received multiple doses of the same medication in transport. Receiving the same medication via a different route constituted a different administration. "Infusions" were defined as medications administered continuously via intravenous (IV) line with an intention to titrate. Medications that were given with a rate, but with a pre-defined dose, such as 1 g of vancomycin, were defined as "bolus medications." If an infusion was stopped at the sending hospital by the CCT team prior to transport, the medication was included in the analysis as a "discontinuation," but not as an infusion. Medications that were discontinued in transport were counted as both a discontinuation as well as an infusion.

Data were analyzed in a descriptive manner.

Results

During the time period of the study, the CCT service performed 8,953 transports, and 239 charts were identified for analysis. Table 1 lists demographic information. Medications were administered by the CCT team to 98.7% of these patients, with only three patients not receiving any medications from the team. Fifty-nine medications were administered in total (Table 2), with 996 instances of administration. Fifteen drugs were each

Mean Age (years)	54.6 (SD = 17.2)
Male Sex	50.2%
Comorbidities	**Number (%)**
COPD	47 (19.7)
Asthma	22 (9.2)
Obesity	56 (23.4)
Pregnancy	3, 1 post-partum (1.3, 0.4)
Cardiac Disease	37 (15.5)
Cancer	38 (15.9)
Diabetes	34 (14.2)
HTN	56 (23.4)
Other Chronic Disease	75 (31.4)
Diagnosis	**Number (%)**
H1N1 confirmed or suspected	38 (15.9)
Pneumonia	109 (45.6)
Abdominal sepsis or pancreatitis	39 (16.3)
Aspiration	16 (6.7)
Other respiratory failure	33 (13.8)
ARDS not otherwise specified	20 (8.4)
Sepsis not otherwise specified	12 (5.0)
APACHE II Score	28.3 (SD = 6.9)
Mode of Transport	
Ground	155
Rotor Wing	77
Fixed Wing	7
Mean Out of Hospital Time in Minutes (Total)	47.2 (SD = 25.0)
Ground Transports	54.2 (SD = 24.7)
Rotor Wing Transports	39.9 (SD = 19.3)
Fixed Wing Transports	84.3 (SD = 34.2)

Table 1. Demographics
Abbreviations: ARDS, acute respiratory distress syndrome; COPD, chronic obstructive pulmonary disease; HTN, hypertension.

administered to only one patient. The mean number of medications per patient was 4.2 (SD = 1.8), of which 1.9 (SD = 1.1) per patient were administered as infusions (Table 2). Fifty-one patients (21.3%) received three or more infusions, with the maximum number of infusions being seven, occurring in one patient transport.

The most commonly administered medications were fentanyl, midazolam, norepinephrine, propofol, and phenylephrine. The 10 most frequently administered medications accounted for 76.7% of all medications given. Table 3 details the doses, route, and frequency of administration of these medications.

Total Number of Medication Administrations	996
Boluses	589
Infusions	391
Inhaled	13
Per Rectum	3
Mean Number of Medications per Patient	4.2 (SD = 1.8)
Mean Number of Boluses per Patient	2.5 (SD = 1.3)
Mean Number of Infusions per Patient	1.9 (SD = 1.1)
Total Number of Unique Medications	59

Table 2. Medications and Fluids in Transport

When considered in terms of therapeutic class, the most commonly administered group of drugs were the sedative/hypnotics, which accounted for 26.1% of all prescription episodes (Table 4).

Although the CCT often continued sedative infusions started at the sending facility, the team did not initiate any infusions for sedation or analgesia during transport, instead using bolus dosing for these medications. However, they did discontinue medications frequently, often stopping sedative infusions and providing boluses (Table 4).

Neuromuscular blocking agents were administered 109 times. Forty-one patients were treated with crystalloid boluses, nine received packed red blood cells, and two patients were transfused fresh frozen plasma (Table 4).

Discussion

These results demonstrate that, even within a relatively homogeneous population of critically ill patients transferred with hypoxemic respiratory failure, a wide range of medications were administered. Patients with hypoxemic respiratory failure were selected for analysis as they are considered to be a resource-intensive population during transport, and in this study, the CCT teams frequently did initiate, titrate, and discontinue continuous infusions, in addition to providing numerous doses of bolused medication. There are few published data on the patterns of medication administration in transport.[2,3] Of the available studies, a previous study from 2006 in pediatric CCT reported findings similar to this study's. Their teams administered 38 IV drugs to

Medication	No. of Boluses	Mean Cumulative Doses	No. of Infusions	Mean Infusion Rates	No. of Boluses and Infusion	No. of Times Discontinued by CCT Team
Fentanyl in mcg or mcg/hr	205	247.1 (SD = 147)	11	132.7 (SD = 84.3)	4	5
Midazolam in mg or mg/hr	111	3.8 (SD = 3.2)	16	8.8 (SD = 5.9)	6	14
Norepinephrine in mcg/min	0	0.0	114	16.19 (SD = 18.5)	0	9
Propofol in mcg/kg/min	0	0.0	83	40.5 (SD = 24.6)	0	16
Phenylephrine in mcg/min	0	0.0	44	100.5 (SD = 86.1)	0	3
Vecuronium in mg/hr	40	10.0 (SD = 4.3)	3	7.0	0	0
Crystalloid Boluses	41	-	-	-	-	-
Lorazepam in mg or mg/hr	37	2.5 (SD = 1.2)	1	10.0	0	1
Rocuronuim in mg	28	82.0 (SD = 34.7)	2	NR	0	1
Vasopressin in units/min	0	0.0	27	0.044 (SD = 0.03)	0	1

Table 3. Ten Most Frequently Administered Medications
Abbreviations: CCT, critical care transport; kg, kilogram; mcg, microgram; mg, milligram.

https://doi.org/10.1017/S1049023X1500494X Published online by Cambridge University Press

	Administrations	Number of Medications in Class	Initiations of Infusions in Transport	Titrations	Discontinuations
Sedative-hypnotics	260	5	0	26	31
Analgesics	220	2	0	0	7
Vasopressors/Ionotropes	211	6	46	75	16
Neuromuscular Blockade	109	5	0	0	2
Crystalloid Boluses	41	2	41	0	0
Antibiotics/Antivirals	40	13	0	0	0
Antiarrhythmics	16	3	4	1	0
Electrolyte Repletion, including TPN	15	8	6	0	0
Bronchodilators	12	2	0	0	0
Blood Product Transfusions	11	2	0	0	0
Heparin Infusion	10	1	0	0	0
Insulin	7 infusions, 1 bolus	1	0	0	0

Table 4. Classes of Medications Provided
Abbreviation: TPN, total parenteral nutrition.

175 patients, and 10 medications accounted for 90% of the administrations.[3]

This study delineated bolus medications and infusions, given the numerous considerations for each type of administration. Bolus medications carry a risk of medication errors given the frequency of administration and the multiple means of delivery.[7] Infusions have other considerations, namely, the need for additional equipment with pumps and dedicated IV lines. Both calculation errors and difficulty with infusion equipment have been cited as common reasons for medication errors.[8] Different clinical areas may use different units for infusions, creating an opportunity for error.

The patterns of medication administration by CCT teams vary with multiple factors, including the patient population and the health care system within which the team is operating.[3] In this study, the CCT team did not start sedative infusions and only titrated propofol for sedation, otherwise electing to provide bolus sedation during the transport. This is reflective of local practice patterns and may not reflect other practices. However, the CCT team frequently started, titrated, and discontinued vasoactive medications, including pressors, ionotropes, and antiarrhythmics.

A small number of drugs were used frequently, with the 10 most frequently administered medications constituting over 75% of administrations. However, the total array of drugs that were used was broad in this study. This discrepancy has important implications. Appreciating the required pharmacy is important for the stocking of medications in transport. Several authors and guidelines have recommended the minimum number and type of medications to be carried in transport.[9,10] While many of the medications administered in this study were included in these lists of recommended transport medications, not all were. Carrying all medications that may be required is not practical, and this should be recognized in advance, as in some circumstances, less frequently used drugs should be prepared for transport purposes prior to the departure of the transport team.[3]

Additionally, in considering the discrepancy between frequency of use and breadth of possible medications, one must consider the risks of medication errors. A systematic review of medication errors has demonstrated that a lack of knowledge about medications may be a factor in errors.[8] Therefore, the risk of medication errors may be exacerbated by the administration of less frequently used medications, as occurred intermittently this study. The Institute for Safe Medication Practices (Horsham, Pennsylvania USA) has issued a list of high alert medications for the acute setting, including adrenergic agonists, anesthetic agents, antiarrhythmics, anticoagulants, and insulin.[11] While errors may not be more common with these medications, the risk to patients in the event of an error is higher. Notably, many of the medications used in transport fall into these categories.

Limitations

This study was a retrospective study, and therefore subject to the limitations of a retrospective review. Additionally, this data set represents only those patients transported with hypoxemic respiratory failure, and therefore, may not represent fully the broader population of all adult patients undergoing transport. However, even in this subset of patients, the diversity and complexity of dosing regimens can be appreciated and potentially can inform broader logistical pharmaceutical considerations, including medication stocking, crew training, and real-time medication administration practices during transport of critically ill patients.

Conclusions

These results demonstrate that, even within a relatively homogeneous patient population of patients transferred with hypoxemic respiratory failure, a wide range of medications were administered. The CCT teams frequently initiated, titrated, and discontinued continuous infusions, in addition to providing numerous doses of bolused medication.

Acknowledgements

The work contained herein was performed at three tertiary care hospitals: Massachusetts General Hospital, Brigham and Women's Hospital, and Beth Israel Deaconess Medical Center, all located in Boston, Massachusetts USA.

References

1. Roeder JR. Flight team configuration of an air medical serivce. *Top Emerg Med*. 1994;16(4):66-72.
2. Gebremichael M, Borg U, Habashi NM, et al. Interhospital transport of the extremely ill patient: the mobile intensive care unit. *Crit Care Med*. 2000;28(1):79-85.
3. Saha AS, Langridge P, Playfor SD. The pattern of intravenous drug administration during the transfer of critically ill children by a specialist transport team. *Paediatr Anaesth*. 2006;16(10):1063-1067.
4. Singh JM, MacDonald RD, Bronskill SE, Schull MJ. Incidence and predictors of critical events during urgent air-medical transport. *CMAJ*. 2009;181(9):579-584.
5. Singh JM, Ferguson ND, MacDonald RD, et al. Ventilation practices and critical events during transport of ventilated patients outside of hospital: a retrospective cohort study. *Prehosp Emerg Care*. 2009;13(3):316-323.
6. Singh JM, Macdonald RD, Ahghari M. Critical events during land-based interfacility transport. *Ann Emerg Med*. 2014;64(1):9-15.
7. Taxis K, Barber N. Ethnographic study of incidence and severity of intravenous drug errors. *BMJ*. 2003;326(7391):684.
8. Keers RN, Williams SD, Cooke J, Ashcroft DM. Causes of medication administration errors in hospitals: a systematic review of quantitative and qualitative evidence. *Drug Saf*. 2013;36(11):1045-1067.
9. Warren J, Fromm RE Jr, Orr RA, et al. American College of Critical Care Medicine. Guidelines for the inter- and intrahospital transport of critically ill patients. *Crit Care Med*. 2004;32(1):256-262.
10. Beninati W, Meyer MT, Carter TE. The critical care air transport program. *Crit Care Med*. 2008;36(7 Suppl):S370-S376.
11. Institute for Safe Medication Practices (ISMP). ISMP list of high-alert medications in acute care settings. ISMP Web site. http://www.ismp.org/tools/highalertmedications.pdf. Published 2014. Updated 2014. Accessed March 12, 2015.