African Journal of Emergency Medicine 8 (2018) 140–144

Contents lists available at ScienceDirect

African Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/afjem

ORIGINAL ARTICLE

A descriptive analysis of endotracheal intubation in a South African Helicopter Emergency Medical Service

Willem Stassen*, Alastair Lithgow, Craig Wylie, Christopher Stein

Department of Emergency Medical Care, University of Johannesburg, South Africa

ARTICLE INFO

Keywords:
Helicopter Emergency Medical Services
Endotracheal intubation
Airway management
Prehospital care

ABSTRACT

Introduction: Helicopter Emergency Medical Services (HEMS) exists to supplement the operations of ground-based emergency care providers, mainly in high acuity cases. One of the important procedures frequently carried out by HEMS personnel is endotracheal intubation. Several HEMS providers exist in South Africa, with a mix of advanced life support personnel, however intubation success rates and adverse events have not been described in any local HEMS operation.

Methods: This was a retrospective chart review of intubation-related data collected by a HEMS operation based in Johannesburg over a 16-month period. First-pass and overall success rates were described, in addition to perceived airway difficulty, adverse events and other data.

Results: Of the 49 cases recorded in the study period, one was excluded leaving 48 cases for analysis. Most cases (n = 34, 71%) involved young male trauma patients who were intubated with rapid sequence intubation. The first pass success rate was 79% (n = 38) with an overall success rate of 98% (n = 47). At least one factor suggesting airway difficulty was present in 29% (n = 14) of cases, with most perceived airway difficulty related to the high prevalence of trauma cases. At least one adverse event occurred in 27% (n = 13) of cases with hypoxaemia, hypotension and bradycardia most prevalent.

Discussion: In this small sample of South African HEMS intubation cases, we found overall and first-pass success rates comparable to those reported in similar contexts.

African relevance

- Prehospital endotracheal intubation has come under scrutiny in many parts of the world.
- In low- and middle-income countries where hospitals are often remote or poorly accessible, prehospital endotracheal intubation might be of value.
- This study explores the safety of prehospital endotracheal intubation within this context.

Introduction

Helicopter Emergency Medical Services (HEMS) exist in many parts of the world and supplement the operations of ground-based emergency care providers, mainly in the area of high acuity patient care. The rationale for funding HEMS is most often on the basis of advanced care and shorter transfer times and the effect that has on improving patient outcomes, although evidence in support of this is mixed and mainly limited to severe trauma [1–4]. HEMS has been a feature of South African prehospital emergency care since the early 1980s, with several private and non-profit entities currently providing HEMS operations in various parts of the country.

One of the key advanced procedures associated with HEMS-level of care is endotracheal intubation (ETI), mainly in the form of rapid sequence intubation (RSI) and performed by a range of providers including physicians, nurses and paramedics [5–7]. Studies of ETI in the HEMS environment generally focus on overall- and first-pass success rates and, less frequently, adverse events (AEs). Published studies have identified overall success rates in HEMS ETI ranging between 96% [8–10] and 100% [6], and a variety of AEs such as hypoxaemia, bradycardia and hypotension with varied prevalences [7,11,12]. Although the vast majority of these studies are descriptive, high success rates and low AE rates in HEMS ETI are frequently attributed to rigorous training, experienced providers, standardised protocols and robust clinical governance procedures [13,14].

In South Africa, HEMS are staffed mainly by paramedics whose

Peer review under responsibility of African Federation for Emergency Medicine.
* Corresponding author.
E-mail address: willem.stassen@uct.ac.za (W. Stassen).

https://doi.org/10.1016/j.afjem.2018.07.002
Received 24 January 2018; Received in revised form 4 May 2018; Accepted 3 July 2018
Available online 26 July 2018

scopes of practice, including airway management, are broadly defined as being at advanced life support level. Although this level of practice uses drug-assisted ETI, there is some variation in practice ranging from sedation-only ETI to RSI [15]. Despite HEMS operations having existed for many decades in South Africa, the ETI success rates, AE profiles and other characteristics of advanced airway management have not been described or compared to others. To this end, our aim was to describe ETI success rates, AE rates, as well as the rate of anticipated airway difficulty and other factors in a South African HEMS service over a 16-month period.

Methods

A retrospective chart review of ETIs done by HEMS crews over a 16-month period was completed. Intubations performed between 1 December 2014 and 30 April 2016 were recorded on a standard airway data form by each crew after the completion of a flight. The aim of this form was to allow for clinical quality monitoring as well as clinical risk mitigation. These forms were submitted anonymously, separate to the standard patient report form, in order to facilitate a self-reporting culture within the service. This form has since evolved into a mobile-accessible online submission document, which was implemented during the latter four months of the study period.

The HEMS, staffed by either degree or certificate/diploma qualified paramedics, is based in the western parts of Johannesburg, an urban city in the Gauteng province of South Africa. Gauteng is the most densely populated province in South Africa, with a land mass area of 18,176 km^2. The HEMS transports private (medical insurance), state, road accident fund and workman's compensation patients from the scene of an incident or as an inter-facility transfer. During the study period, the HEMS service completed on average 22 cases per month and roughly 260 per annum. In South Africa, HEMS is normally activated as a back-up resource by ground emergency medical services after consultation with a medical officer or similar.

Within this specific HEMS, a standardised protocol is followed whenever a prehospital intubation is attempted. This process is outlined in Fig. 1. ETI is generally indicated in any patient in which an airway needs to be established or secured, adequate oxygenation and ventilation is needed or in cases where the clinical course is predicted to deteriorate before or during HEMS transfer. All patients are pre-oxygenated for 3–5 min while airway assessment, equipment checks and premedication (e.g. analgesia, either morphine or ketamine), where indicated, is administered. During the last six months of the data collection period, apnoeic oxygenation was added to the protocol, in the form of a nasal cannula placed at the end of the preoxygenation period.

Drug combinations used to facilitate ETI vary depending on the qualification of the highest qualified paramedic. Degree qualified paramedics perform RSI, with a choice of ketamine or etomidate for induction and suxamethonium or rocuronium for primary neuromuscular blockade. Certificate or diploma qualified paramedics perform sedation-only ETI, with either midazolam alone or a combination of midazolam and morphine. Endotracheal tube position is confirmed with waveform capnography and auscultation of the chest.

After three unsuccessful ETI attempts, a standard difficult airway approach is followed involving equipment changes if necessary (e.g. laryngoscope blade), adjunctive airway manoeuvres to improve laryngoscopic view, use of a bougie, use of an alternative intubating device, placement of an extraglottic airway or surgical access.

All patients are mechanically ventilated during HEMS transfer with ongoing post-intubation sedation using bolus doses of midazolam or ketamine, and morphine for analgesia as required. Additional long-acting paralysis is not routinely performed after RSI, only in cases where it is required to facilitate adequate mechanical ventilation or indicated based on the specific pathology of the patient.

For the purposes of this study, a predicted airway difficulty was defined as a predetermined factor that either relates to the condition or injuries of the patient, or the anatomical features of the patient that may predict difficulty with ETI. An intubation attempt is defined as the placing of a laryngoscope blade inside the mouth, with the aim of viewing the glottis. Intubation success is defined as placement of the distal end of the endotracheal tube and cuff in the trachea, as confirmed by waveform capnopgraphy and chest auscultation. Success is reported as first pass, meaning intubation success after a single attempt, or overall, meaning intubation success after more than one attempt.

Adverse events are defined as clinical or equipment factors that occurred during or immediately after intubation that have the potential to negatively impact the patient's condition. AEs include hypotension (systolic blood pressure < 90 mmHg), hypoxemia (SpO_2 < 90%), bradycardia (heart rate < 60 beats/minute), additional medication required (to re-paralyse or re-sedate the patient between attempts after initial medication doses), cardiac arrest (any pulseless rhythm during or immediately after an attempt at ETI whether successful or not), equipment failure (malfunctioning equipment that is essential for endotracheal intubation) and failed intubation (total inability to pass an ETT).

Data from the airway data forms (both paper-based and electronic) were manually extracted and entered into a spread sheet application for descriptive analysis.

Ethical approval for this study was obtained by the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg (clearance number: REC-01-136-2016).

Results

A total of 49 ETI records were extracted and reviewed. A single record did not disclose the number of intubation attempts and was therefore excluded from analysis. Tables 1 and 2 describe the endotracheal intubations sampled. The majority of patients intubated were male (n = 34, 71%) who were intubated in the urban (n = 28, 58%), prehospital setting (n = 40, 83%) using RSI (n = 34, 71%). The induction agent of choice was ketamine (n = 31, 65%), while the paralytic of choice was suxamethonium (n = 33, 69%).

The most prevalent indications for intubation were traumatic brain injury (n = 25, 52%) and multisystem trauma (n = 11, 23%) (Table 3). Three patients (6%) were intubated for resuscitation in cardiac arrest. Multiple indications applied in some cases.

Only 17% (n = 8) of cases had no predicted airway difficulty on assessment. In 58% (n = 28) of intubations undertaken in this period, there were two or more factors that predicted a difficult airway or intubation. The most prevalent factor predicting a difficult airway was the presence of a suspected cervical spine injury, thus necessitating in-line spinal motion restriction during laryngoscopy. Table 4 summarises the predicted airway difficulty data.

The median Glasgow Coma Scale (GCS) for the sample was 6/15 before intubation and 2/10 after intubation. Most patients were tachycardic and normotensive before and after intubation however, the post-intubation systolic blood pressures were marginally lower when compared to the pre-intubation systolic blood pressure (127 mmHg versus 120 mmHg). The median pre-intubation pulse oximetry saturation levels were 93%, while post-intubation saturations increased to 100%. These results are summarised in Table 5.

The first pass success rate (Table 6) in this sample was 79% (n = 38), while the overall success rate was 98% (n = 47). There was only one failed intubation in the 16-month period that was reviewed.

Adverse events occurred in a third of intubations (Table 7). The most common AEs were hypotension and hypoxaemia, occurring with a prevalence of 15% (n = 7) and 13% (n = 6), respectively. In four percent (n = 2) of intubations more than two AEs occurred. In both of these instances, hypoxaemia (n = 1) or equipment failure (n = 1) lead to an additional dose of medication being required and bradycardia. In both these instances, suxamethonium was used.

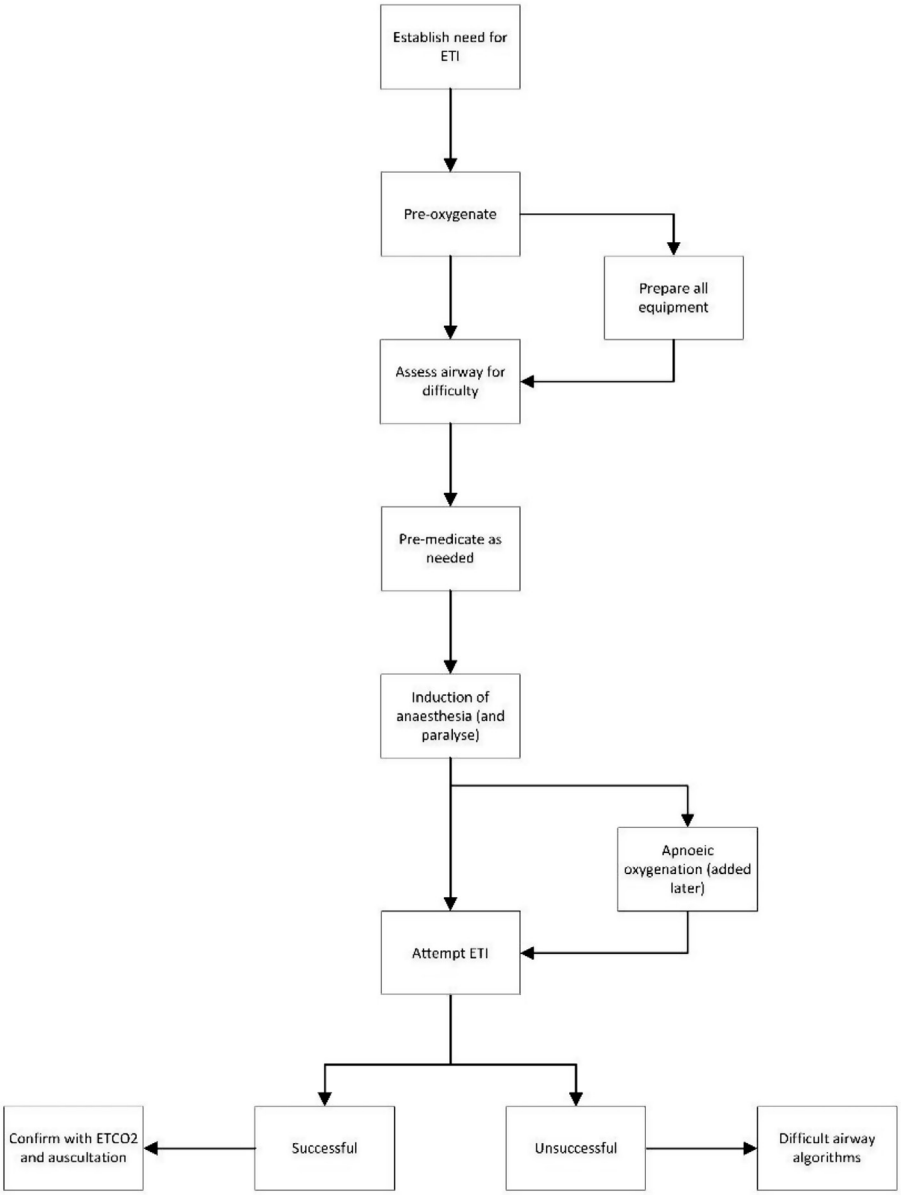

Fig. 1. Prehospital intubation protocol.

Table 1
Descriptive data.

Gender, n (%)	Male	34 (71)
	Female	14 (29)
Age in years, median (IQR)		36 (21)
Setting of Intubation, n (%)	Prehospital	40 (83)
	In-hospital: Emergency Centre	8 (17)
Location of Intubation, n (%)	Urban	28 (58)
	Rural	20 (42)

IQR, inter-quartile range.

Table 2
Drugs used for endotracheal intubation.

Type of Induction, n (%)	No Induction Required	4 (8)
	Deep Sedation	10 (21)
	Rapid Sequence Intubation	34 (71)
Induction Agents, n (%)	Etomidate	5 (10)
	Ketamine	31 (65)
	Midazolam	4 (8)
	Midazolam and Morphine	4 (8)
Paralytic Agents, n (%)	Suxamethonium	33 (69)
	Rocuronium	1 (2)

Discussion

This retrospective cases series of ETI in an urban HEMS service provides the first HEMS-specific South African data on ETI perceived difficulty, success rates, AEs and other variables. At least one factor suggesting airway difficulty was identified in 29% of cases – the most common being restricted cervical spine movement due to suspected injury or fluid in the airway. We identified a first pass success rate of 79% and an overall ETI success rate of 98% in a sample comprised mainly of adult trauma cases intubated with RSI. At least one AE occurred in 27% of cases, with hypotension and hypoxaemia being the most common.

Perceived difficult airway factors identified in this study seem to be associated mostly with the large proportion of trauma-related cases, reflecting the high prevalence of trauma burden in South Africa generally [16]. Comparisons with other published data on difficult airways in the HEMS environment are challenging as most of these report on

Table 3
Indications for endotracheal intubation.

Indications for Intubation, n (%)	Traumatic Brain Injury	25 (52)
	Other Multisystem Trauma	11 (23)
	Respiratory Failure	7 (15)
	Airway Obstruction	7 (15)
	Facial Trauma	7 (15)
	Burns	5 (10)
	Cardiac Arrest	4 (8)
	Decreased LOC with Threatened Airway	2 (4)
	Sepsis	1 (2)
	Stroke	1 (2)
	Seizure Disorder	1 (2)
	Chest Trauma (with flail segment)	1 (2)

LOC, level of consciousness.

Table 4
Predicted airway difficulty.

Predicted Airway Difficulty, n (%)	Suspected Cervical Spine Injury	38 (79)
	Fluid in Airway	17 (35)
	Trauma	13 (27)
	Obesity	9 (19)
	Short Neck	7 (15)
	Large Tongue	6 (13)
	Burns	5 (10)
	Thick Neck	4 (8)
	Airway Obstruction	3 (6)
	Facial Hair	2 (4)
	Reduced Hyomental Distance	2 (4)
	Restricted Mouth-opening	2 (4)
	Reduced Thyro-hyoid Distance	1 (2)
	Reduced Temporo-mandibular Protrusion	1 (2)
	Stridor	1 (2)
Number of difficulties, n (%)	0	6 (13)
	1	14 (29)
	2	11 (23)
	3	10 (21)
	> 3	7 (15)

Table 5
Clinical parameters.

	Pre-intubation (IQR)	Post-Intubation (IQR)
GCS	6 (6)	2 (0)
Heart rate	112 (35)	108 (34)
Respiratory rate	20 (16)	8 (9.3)
SpO_2	93% (8.8%)	100% (3%)
FiO_2	0.88 (0.4)	1.0 (0)
SBP	127 (33)	120 (41)
DBP	80 (33)	81 (27)

GCS, Glasgow Coma Scale; IQR, inter-quartile range; SpO_2, arterial oxygen saturation; FiO_2, fraction of inspired oxygen; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 6
Intubation attempts.

One attempt, n (%)	38 (79)
Two attempts, n (%)	6 (13)
Three attempts, n (%)	3 (6)
Failed intubation, n (%)	1 (2)

actual difficulty as estimated by laryngoscopic view while our data simply reflected a subjective estimate of possible difficulty. Nevertheless, two other studies including data on subjective estimates of airway difficulty in HEMS services suggest much lower estimates of between roughly 2% [17] and 20% [18] either as a general impression of difficulty or as a prevalence of factors associated with perceived difficulty.

Table 7
Adverse events.

Adverse events, n (%)	Hypotension (SBP < 90)	7 (15)
	Hypoxaemia (SpO_2 < 90%)	6 (13)
	Bradycardia	2 (4)
	Additional medication required	2 (4)
	Cardiac arrest	1 (2)
	Equipment failure	1 (2)
	Failed intubation	1 (2)
Adverse event rates, n (%)	0	33 (69)
	1	13 (27)
	> 2	2 (4)

SBP, systolic blood pressure; SpO_2, arterial oxygen saturations.

Several other international studies have reported on non-physician ETI success rates in the HEMS environment. The first pass success rate observed in this study was towards the higher end of those reported in similar studies, which range between 59% [8] and 87% [19]. Although pooling success rates from all operational environments and not just HEMS, a recent meta-analyses identified a non-physician RSI first pass success rate of 78% which is very similar to ours [20]. The overall ETI success rate obtained from our data is in the middle of the range reported in similar studies, which is between 96% [8-10] and 100% [6]. It also compares favourably with overall success rates from two meta-analyses reporting non-physician RSI and ETI (both 97%) [21]. In the series of ETI cases presented here, the presence of 10 (21%) non-RSI ETIs did not appear to have an effect on overall success rates. The only failed intubation was an RSI.

Few reports of AEs during non-physician HEMS ETI are available in the literature for comparison with our data. Reported instances of hypotension in a similar environment range between 0.9% [22] and 17.6% [23], thus placing the current study's rate of 15% towards the higher end of this spectrum. Although it is difficult to establish what may have caused this from the available data, the 21% prevalence of non-RSI ETI which is dependent on sedation with midazolam, typically at relatively high doses, without paralysis may be partially responsible. Comparable reported data on hypoxia during ETI range between 0% [24] and 62% [12], with this study's hypoxaemia prevalence (13%) at the lower end of this range. Lastly, comparable reported rates of bradycardia and cardiac arrest range between 1% [7] and 35% [25], and 0% [26] and 4% [27], respectively. The current study's data thus falls within the middle to lower range of these reported AEs. All reported cases of bradycardia occurred when a second dose of suxamethonium was administered.

The only other South African data on pre-hospital RSI (albeit not in a HEMS environment) reported by Gunning et al. [28] identified hypotension, hypoxaemia and bradycardia in 4.7, 2.3 and 3.5% of cases, respectively. These proportions are all lower than those in the current series, however it is important to note that the cases reported by Gunning *et al.* were all facilitated with the use of neuromuscular blockers and did not utilise sedation only which may have had an effect, particularly on rates of hypotension.

This study has several limitations. All data were self-reported and thus may possibly have been biased, including the reporting of AEs. The small sample size did not allow for more detailed comparative analyses of variables between RSI and non-RSI groups, or other comparisons, which may have assisted in explaining some of the data. Data on laryngoscopic view (Cormack-Lehane grade) were not available for the entire dataset and have consequently been omitted from this series making statements about airway difficulty less certain – these are based only on factors predicted to be associated with difficulty rather than the actual laryngoscopic view.

In this small sample of South African HEMS ETI cases, we found overall and first-pass success rates comparable to those reported in

similar contexts. We identified a 27% AE rate, with a hypotension rate in the upper end of the range reported in similar studies. Further research is needed using a larger sample of HEMS ETI cases in order to corroborate these results and to gain a more detailed understanding of factors affecting AEs.

Conflicts of interest

This project was funded in full by the Emergency Care Research Unit of ER24 (https://www.er24.co.za/). The authors declared no further conflicts of interest.

Dissemination of results

Data were provided to ER24 to guide their clinical governance processes.

Author contributions

WS conceived of the project, collected and analysed data and drafted and approved the final manuscript. AL conceived of the project, collected data and approved the final manuscript. CW analysed data and approved the final manuscript. CS analysed data, revised and approved the final manuscript.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.afjem.2018.07.002.

References

[1] Galvagno SM, Haut ER, Zafar SN, Millin MG, Efron DT, Koenig GJ, et al. Association between helicopter vs ground emergency medical services and survival for adults with major trauma. JAMA 2012;307(15):1602–10.
[2] Andruszkow H, Lefering R, Frink M, Mommsen P, Zeckey C, Rahe K, et al. Survival benefit of helicopter emergency medical services compared to ground emergency medical services in traumatized patients. Crit Care 2013;17(3):R124.
[3] Galvagno SM, Sikorski R, Hirshon JM, Floccare D, Stephens C, Beecher D, et al. Helicopter emergency medical services for adults with major trauma. Cochrane Database Syst. Rev. 2015;15(12):CD009228.
[4] Brown BS, Pogue KA, Williams E, Hatfield J, Thomas M, Arthur A, et al. Helicopter EMS transport outcomes literature: annotated review of articles published 2007–2011. Emerg. Med. Int. 2012;876703.
[5] Chesters A, Keefe N, Mauger J, Lockey D. Prehospital anaesthesia performed in a rural and suburban air ambulance service staffed by a physician and paramedic: a 16-month review of practice. Emerg. Med. J. 2014;31(1):65–8.
[6] Andrew E, de Wit A, Meadley B, Cox S, Bernard S, Smith K. Characteristics of patients transported by a paramedic-staffed helicopter emergency medical service in Victoria, Australia. Prehosp. Emerg. Care 2015;19(3):416–24.
[7] Von Vopelius-Feldt J, Benger JR. Prehospital anaesthesia by a physician and paramedic critical care team in Southwest England. Eur. J. Emerg. Med. 2013;20(6):382–6.
[8] Hiestand B, Cudnik MT, Thomson D, Werman HA. Rocuronium versus succinylcholine in air medical rapid-sequence intubation. Prehosp. Emerg. Care 2011;15(4):457–63.
[9] Merlin MA, Safdar H, Calabrese S, et al. Prehospital rapid sequence intubation in an emergency medical services system with two advanced life support providers. Prehosp. Disaster Med. 2010;25(4):341–5.
[10] Tollefsen WW, Brown 3rd CA, Cox KL, Walls RM. Two hundred sixty pediatric emergency airway encounters by air transport personnel: a report of the air transport emergency airway management (NEAR VI: "A-TEAM") project. Pediatr Emerg Care 2013;29(9):963–8.
[11] Bernard S, Smith K, Foster S, Hogan P, Patrick I. The use of rapid sequence intubation by ambulance paramedics for patients with severe head injury. Emerg. Med. (Fremantle, WA) 2002;14(4):406–11.
[12] Davis DP, Douglas DJ, Koenig W, Carrison D, Buono C, Dunford JV. Hyperventilation following aero-medical rapid sequence intubation may be a deliberate response to hypoxemia. Resuscitation 2007;73(3):354–61.
[13] Bernard SA, Nguyen V, Cameron P, et al. Prehospital rapid sequence intubation improves functional outcome for patients with severe traumatic brain injury: a randomized controlled trial. Ann. Surg. 2010;252(6):959–65.
[14] Lockey DJ, Crewdson K, Lossius HM. Pre-hospital anaesthesia: the same but different. BJA 2014;113(2):211–9.
[15] Health Professions Council of South Africa. Capabilities of emergency care providers; 2011 [Online]. Available from: http://www.hpcsa.co.za/Uploads/editor/UserFiles/downloads/emergency_care/capabilities_baa_eae_ecp_ect_jul_2013_final.pdf.
[16] Matzopoulos R, Prinsloo M, Pillay-van Wyk V. Injury-related mortality in South Africa: a retrospective descriptive study of postmortem investigations. Bull. World Health Org. 2015;93(5):303–13.
[17] Gunning M, O'Loughlin E, Fletcher M, Crilly J, Hooper M, Ellis DY. Emergency intubation: a prospective multicentre descriptive audit in an Australian helicopter emergency medical service. Emerg. Med. Journal 2009;26(1):65–9.
[18] Helm M, Hossfeld B, Schäfer S, Hoitz J, Lampl L. Factors influencing emergency intubation in the pre-hospital setting—a multicentre study in the German Helicopter Emergency Medical Service. BJA. 2006;96(1):67–71.
[19] Sing RF, Rotondo MF, Zonies DH, et al. Rapid sequence induction for intubation by an aeromedical transport team: a critical analysis. Am. J. Emerg. Med. 1998;16(6):598–602.
[20] Fouche PF, Stein C, Simpson P, Carlson JN, Doi SA. Nonphysician out-of-hospital rapid sequence intubation success and adverse events: a systematic review and meta-analysis. Ann. Emerg. Med. 2017;70(4):449-459.
[21] Hubble MW, Brown L, Wilfong DA, Hertelendy A, Benner RW. A meta-analysis of prehospital airway control techniques part I: orotracheal and nasotracheal intubation success rates. Prehosp. Emerg. Care 2010;14(3):377–401.
[22] Perkins ZB, Wittenberg MD, Nevin D, Lockey DJ, O'Brien B. The relationship between head injury severity and hemodynamic response to tracheal intubation. J. Trauma 2013;74(4):1074–80.
[23] Elofson KA, Rhoads SF, Tang A, Gaither JB, Patanwala AE. Long-acting neuromuscular blocker use during prehospital transport of trauma patients. Air Med. J. 2013;32(4):203–7.
[24] Sing RF, Reilly PM, Rotondo MF, Lynch MJ, McCans JP, Schwab CW. Out-of-hospital rapid-sequence induction for intubation of the pediatric patient. Acad Emerg. Med. 1996;3(1):41–5.
[25] Dunford JV, Davis DP, Ochs M, Doney M, Hoyt DB. Incidence of transient hypoxia and pulse rate reactivity during paramedic rapid sequence intubation. Ann. Emerg. Med. 2003;42(6):721–8.
[26] Vilke GM, Hoyt DB, Epperson M, Fortlage D, Hutton KC, Rosen P. Intubation techniques in the helicopter. J. Emerg. Med. 1994;12(2):217–24.
[27] Ochs M, Davis D, Hoyt D, Bailey D, Marshall L, Rosen P. Paramedic-performed rapid sequence intubation of patients with severe head injuries. Ann. Emerg. Med. 2002;40(2):159–67.
[28] Gunning M, Perkins Z, Crilly J, von Rahden R. Paramedic rapid sequence induction (RSI) in a South African emergency medical service: a retrospective observational study. SAMJ 2013;103(9):632–7.