Original Article

The Airway App: exploring the role of smartphone technology to capture emergency front-of-neck airway experiences internationally

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Summary

In this exploratory study we describe the utility of smartphone technology for anonymous retrospective observational data collection of emergency front-of-neck airway management. The medical community continues to debate the optimal technique for emergency front-of-neck airway management. Although individual clinicians infrequently perform this procedure, hundreds are performed annually worldwide. Ubiquitous smartphone technology and internet connectivity have created the opportunity to collect these data. We created the 'Airway App', a smartphone application to capture the experiences of healthcare providers involved in emergency front-of-neck airway procedures. In the first 18-month period, 104 emergency front-of-neck airway management reports were received; 99 (95%) were internally valid and unique from 21 countries. Eighty-one (82%) were performed by non-surgeons and 63 (64%) were 'cannot intubate, cannot oxygenate' emergencies. Overall first-attempt success varied by technique; 45 scalpel–bougie cricothyroidotomy (37 first-attempt success), 25 surgical cricothyroidotomy (15 first-attempt success), eight cannula cricothyroidotomy (five first-attempt success), six wire-guided cricothyroidotomy (three first-attempt success) and 15 tracheostomy reports (11 first-attempt success). The most commonly reported positive human factors were good communication, good teamwork and/or skilled personnel. The most commonly reported negative human factors were fixation on multiple tracheal intubation attempts, delay in initiating emergency front-of-neck airway and/or the failure to plan for failure. Due to the anonymous nature of reporting, reports are open to recollection bias and spurious reporting. We conclude collection of data using a smartphone application is feasible and has the potential to expand our knowledge of emergency front-of-neck airway management.

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Introduction

Establishing an emergency front-of-neck airway (eFONA) [1] may be the only way to save a patient's life in an airway emergency, including a 'cannot intubate, cannot oxygenate' (CICO) situation [2].

Circumstances in which individual healthcare providers are required to perform eFONA are rare [3–5]. As a result, there is considerable uncertainty regarding which eFONA technique(s) is/are most effective [6, 7]. However, there is some evidence available. Beyond individual clinical experience, evidence can be gleaned from published case reports, systematic reviews [8], closed claims studies [9], national audit projects [10, 11], surveys [12] and registries [4, 12], but many cases remain unreported.

The idea of collecting a large case series electronically is not new. The 4th National Audit Project (NAP4) of the Royal College of Anaesthetists and the Difficult Airway Society reported on 80 cases of eFONA collected prospectively from the fields of anaesthesia, emergency medicine and intensive care. These were collected from 307 hospitals over a one-year period (September 2008 to August 2009) [10]. These observational data were collected electronically and securely while maintaining the anonymity of both clinicians and patients. Despite collecting data on a significant number of eFONA events, NAP4 has arguably increased, rather than resolved, the argument over which is the most effective technique [6, 7, 13, 14].

The NAP4 study used stationary computers for secure data entry. Since that time, the use of mobile smartphone technology in healthcare has become ubiquitous. Mobile internet-linked devices (especially smartphones) enable point-of-care communication, access to electronic medical records, and the use of clinical software applications as diagnostic and management aids [15, 16]. Applications can also be used to upload information. Widespread access to the internet and smartphone technology presents a unique opportunity to collect anonymised data from a wide range of healthcare providers and combine this into aggregated data. This type of large-scale observational methodology may be fruitful in examining clinically infrequent procedures that are difficult, if not impossible, to study within a randomised controlled trial methodology [17].

We have created the 'Airway App' for smartphones as a platform to enable healthcare providers to report their anonymised experiences of eFONA procedures. Collection of a large number of cases will enable extraction of aggregated data that better describes the range of events taking place. Ultimately, this may enable analysis of data to explore factors and techniques that are associated with increased rates of success or failure. Our hypothesis was that by combining the experiences of many, we can assist other clinicians in future decision making for individual patients. In this provisional report, we will:

1 Describe the purpose and the development of the Airway App;
2 Explore the uptake and use of application technology as an instrument for observational data gathering by healthcare providers; and
3 Present the first 18 months of eFONA data collected through the Airway App.

Methods

Ethical opinion was sought before release of the Airway App. Our local ethics board (Fraser Health Research Ethics Board, Fraser Health Region, British Columbia, Canada) determined this was an anonymous quality improvement and evaluation initiative which did not require ethical approval.

The Airway App includes a detailed questionnaire enabling healthcare providers to record their first-hand eFONA experiences. The content of the questionnaire was created by canvassing opinions from airway experts in anaesthesia, emergency medicine and intensive care medicine from various countries (see Acknowledgements). Balance was sought between collecting all details of the procedure from the user while avoiding 'questionnaire fatigue', whereby the participant regards the questionnaire as too long to complete. Questions were checked for ease of use, flow, and omissions by a number of non-airway experts from various medical fields. The application was then trialled by 21 anaesthetic and 10 emergency medicine resident volunteers at the University of British Columbia, Canada, who entered data on virtual patients in order to assess flow, content, and logic of data entry.

The international release of the Airway App was on 11 June 2016. Awareness of the existence and potential use of the application was promoted through presentations and discussions by the authors at airway-related local, national and international meetings, through social media, and in various podcasts [18, 19]. The application has been available for download free-of-charge on the App Store (Apple Inc., Cupertino, CA, USA) and Google Play (Google, Mountain View, CA, USA), and through the website www.airwaycollaboration.org. The conditions of use of the application, which users must accept before gaining access to its content, include accepting that the submitted data may be used in publications (such as this article) that summarise data for education.

To become familiar with the format and questionnaire, participants were able to enter fictitious reports. These were separated from real reports by an initial forced-choice binary question in the eFONA questionnaire: 'Are you wishing to: 1. Play/check out this app: Not a real case?; or 2. Report a real case?'. Importantly, no patient-identifying information was recorded. The questionnaire includes: indications for the procedure; equipment used; sequence of events; and complications. We also sought the healthcare providers' feedback on what aspects of the eFONA technique worked, what did not, and why. The country of origin of the report and the role of the healthcare practitioner entering the report (e.g. paramedic, surgeon etc.) were the only healthcare provider baseline characteristics recorded. The full questionnaire can be reviewed at www.airwaycollaboration.org.

The single criterion for recording an eFONA procedure was that the person reporting the procedure had either performed or directly observed the procedure. Therefore, the healthcare provider reporting the events on the Airway App questionnaire was not necessarily the operator who had performed the procedure. This raised the possibility that more than one entry may have been reported from a single patient encounter. To overcome this, when analysing the data, we excluded duplicate entries by assuming that any procedure performed in the same country, on the same date, with the same technique, on a patient of the same sex was a duplicate.

Reports recorded by the user as a real case were checked for internal validity. Other data recorded through the use of Google Analytics (https://analytics.google.com/) included the number of visits to the application website, number of reports initiated and completed, and whether the user was a new or returning user. Although anonymous, all completed reports were stored on a secure server.

Results

During the first 18-month period of application use (from June 2016 to December 2017) the Airway App was viewed 2183 times, and 1671 application sessions or interactions with the application were initiated. Out of the 1671 initiated sessions, 1480 (89%) used a smartphone and 1347 (81%) were from a new application user, with the remaining being returning users. Out of the 1671 initiated sessions, 695 (42%) reports were completed; of these 104 (15%) stated the user was recording a real patient eFONA procedure. Five out of the 104 reported cases lacked internal validity (conflicting details of the patient, location or circumstances of the procedure) leaving 99 reports. Analysis of details included in each of these 99 reports indicated that each report was unique and was not a duplicate entry.

The median (IQR [range]) time to complete the questionnaire was 418 (332–587 [131–902]) s. The 99 patient reports were recorded from 21 different countries (Table 1). The majority (82%) of eFONA procedures was performed by non-surgeons (Table 2). In 85 (86%) reports the events had occurred in the previous five years (2013–2017).

Patients were men in 73 (74%) cases and patient body mass index was > 30 kg.m^{-2} in 56 (57%) reports. Reports included three pregnant patients and five children (< eight years old). The most common reason for eFONA was a CICO situation (Table 3).

Before initiating eFONA, oxygen saturation was $< 85\%$ in 61 (61%) reports. Tracheal intubation was attempted one to two times in 47 (47%) reports, three to four times in 23 (23%) reports, $\geq$ five times in 13 (13%) reports, and not attempted in 16 (16%) reports. Waveform capnography was used in 48 (48%) reports to confirm eFONA placement. Out of the 64 reports describing CICO events, rescue oxygenation using a supraglottic airway device was attempted in 35 and a neuromuscular blocking agent was administered before initiating eFONA in 29.

Table 1 Country of origin of the 99 real patient emergency front-of-neck airway (eFONA) procedures as reported to the Airway App. Values are numbers.

South Africa	19
USA	19
Canada	18
Australia	10
Netherlands	7
UK	6
New Zealand	3
Germany	2
Sudan	2
Sweden	2
Belgium	1
Chile	1
Czech Republic	1
Denmark	1
Haiti	1
Ireland	1
India	1
Italy	1
Portugal	1
Saudi Arabia	1
Turkey	1

Table 2 Specialty performing the emergency front-of-neck airway (eFONA) procedure in cases reported via the Airway App. Values are number (proportion).

Anaesthesia	32 (32%)
Emergency medicine	22 (22%)
Surgery	18 (18%)
Paramedic	17 (17%)
Intensive care	5 (5%)
Other	5 (5%)

First attempt at eFONA was successful in 71 (72%) reports. Success rates according to first-choice technique are shown in Table 4. Out of the 64 CICO reports, first attempt of eFONA was successful in 44. In both situations, the scalpel–bougie technique was the most commonly used and was the technique with the highest first-attempt success rate. Success rates by first-choice technique in CICO are shown in Table 4. In the 20 reports that included details of a second eFONA attempt, scalpel–bougie cricothyroidotomy was successful in 10 out of 10 attempts, open surgical tracheostomy in five out of five attempts, wire-guided cricothyroidotomy in none out of two attempts and open surgical tracheostomy in two out of three attempts. The most common reason cited for failure of any technique was 'inability to access the airway with the chosen technique'. Three deaths occurred in the setting of eFONA failure and 12 deaths occurred despite eFONA success.

Out of the eight reports describing use of a narrow-bore cannula cricothyroidotomy, two reported using a purpose-made cannula, five used an intravenous cannula and in one, the cannula type was reported as unknown. The cannula was attached to a commercially available flow-regulated oxygenation

Table 3 Indications for 99 emergency front-of-neck airway (eFONA) reports as entered into the Airway App. Values are number (proportion).

Indication	Number (%) of reports[a]
'Cannot intubate, cannot oxygenate'	64 (65%)
Obstructing airway pathology	45 (45%)
Respiratory arrest	26 (26%)
Cardiac arrest	26 (26%)
Facial trauma	15 (15%)
Blunt neck trauma	10 (10%)
Anaphylaxis	10 (10%)
Critical illness with decreased physiological reserve	9 (9%)
Head and neck infection	9 (9%)
Penetrating neck trauma	8 (8%)
Foreign body	8 (8%)
Emergency ear nose and throat (ENT) surgery	6 (6%)
Airway management for emergency surgery (not ENT)	4 (4%)

[a]Numbers and percentages are not additive as a single report may have ≥ 1 indication.

Table 4 First-attempt success of emergency front-of-neck airway (eFONA) rescue by technique, for all reports (n = 99) and 'cannot intubate, cannot oxygenate' (CICO) events (n = 64). Values are number and denominator.

	All eFONA rescue n = 99	eFONA for CICO n = 64
Scalpel–bougie cricothyroidotomy	37/45	25/30
Open cricothyroidotomy	15/25	7/13
Cannula cricothyroidotomy	5/8	5/8
Wire-guided cricothyroidotomy	3/6	2/5
Open tracheostomy	9/12	3/5
Percutaneous tracheostomy	2/3	2/3

device in only one report. Homemade devices (e.g. a series of three-way stopcocks) were used in five reports. Pressure-regulated oxygenation (i.e. jet ventilation) was not used in any reports.

Self-reporting of team dynamics and other factors influencing eFONA procedures were also explored. In general, positive factors outnumbered negative factors. Good communication, good teamwork and skilled personnel were the three most commonly reported positive factors (together reported in 82 (83%)). The positive presence of either a stated airway strategy or shared mental model was cited in 58 reports (59%). Delay in proceeding to eFONA, fixation on multiple tracheal intubation attempts and/or the failure to plan for failure were the three most common negative factors (together reported in 34 (34%)). Sedating or anesthetising a patient when an awake technique was indicated was recorded in 11 reports (11%). In 12 (12%) reports, eFONA was not performed by the most skilled operator, despite their availability. Out of these 12 procedures, 10 (83%) failed on the first attempt. A team debriefing occurred in 64 reports (65%).

Discussion

The goals of this article were to describe the purpose and development of the Airway App, to explore its uptake and use for observational data gathering, and present the first 18 months of results. During this time period, promotion of the application occurred during conferences and meetings, informal academic networking and through the use of social media. As a result of this informal promotion process, the application was viewed over 2000 times and accessed over 1600 times. Although the application can be accessed using smartphone-, desktop- or tablet-based technologies, the vast majority accessed, and completed, reports via a smartphone. Of the reports submitted, 95% were internally valid and interpretable. Cases were reported from multiple countries and all relevant specialties. Overall, we believe we have shown that it is possible to gather eFONA procedural information using smartphone technology and have demonstrated proof-of-concept.

Internationally there remains uncertainty as to which technique for eFONA is best. In 2015, the UK Difficult Airway Society published guidelines recommending use of a scalpel–bougie technique for eFONA [20] and this was subsequently endorsed by other anaesthetic organisations and a surgical organisation in the UK [2]. In contrast, the Australian and New Zealand College of Anaesthetists has also recently published guidelines advocating both needle- and scalpel-based approaches [21]. A large data set of eFONA cases is likely to be of benefit in examining this question further. Current recent data sets include the Danish Anaesthesia Database (27 cases) [22] and NAP4 (80 cases) [10]. We have collected data on 99 cases in the first 18 months of the Airway App. This information suggests that users are willing to invest the time and effort into reporting eFONA cases using application technology. It also suggests that improved dissemination may generate substantial numbers of eFONA reports for analysis.

The Airway App offers the participant a new platform to share their eFONA experiences. Before the Airway App, eFONA experiences were usually shared at a local level or through publication. Not all healthcare providers publish their experiences. In addition, even if the healthcare provider did make the effort to submit their case report, if guidelines were followed, these case reports may not be considered 'publishable' due to a lack of novel information. The only means to capture these experiences then would be through enrolment in registries [22] and audits [10]. Such initiatives are usually limited to a specific time and/or geographic region for data-capture. The Airway App now provides a means for healthcare providers to share their eFONA experiences irrespective of time or location.

Comparing our data to recently published reports may give an indication of its usefulness. The Danish Anaesthesia Database reported that the indication for eFONA was CICO in 70% of cases and reported first-attempt success in 85% and no major morbidity or mortality [22]. The NAP4 reported first-attempt success of 70% with a failure rate of 15% and permanent morbidity or mortality in 25% of patients [10, 11]. In our dataset of 99 reports, 65% were CICO emergencies, first-attempt success rate was 71% and mortality was 15%; our results are, therefore, broadly consistent with the two most recently reported databases.

Cases reported to the Airway App included both needle- and scalpel-based approaches and we were able to use the aggregated data to explore how first-attempt

success rates varied with technique. With the current number of reports, particularly with cannula-based eFONA techniques reported in only eight reports, it would be wrong to draw strong conclusions about relative success rates, and our analysis is exploratory at this stage. As numbers accumulate, this may become feasible. The cases reported also have the potential to explore matters such as good practice (limiting attempts at tracheal intubation, inserting a supraglottic airway and providing neuromuscular blockade during CICO), whether the most experienced airway operator should always perform the rescue technique and human factors in eFONA procedures. Although the data reported here show such an analysis is feasible, we again recommend the accumulation and analysis of a larger dataset in order to combat our current data fragility before conclusions are made. Due to the limited size of the dataset, we do not recommend practice changes based on the currently reported results.

Several limitations of the Airway App require highlighting. Currently, the Airway App is only available in English. In addition, we did not collect patient identifiers, so details of the reported patient encounters cannot be verified. The data represent a retrospective observational study dependent on the memory of healthcare workers who are sufficiently motivated to use the application. This population of 'airway interested' application users may lead to a biased sample. There is also the possibility that individuals are more likely to report cases where there has been a good outcome. Therefore, it is perhaps likely that the data reported are essentially 'optimistic'. Conversely, it may be that a patient encounter is recalled in detail due to failure of the approach. As 14% of cases reported to the Airway App had taken place before 2013, there may be some historical reporting errors. It is likely that, with the increasing uptake of the application, the proportion of historical case entries would decrease as users report cases contemporaneously. There is also a possibility that individuals may enter information erroneously, either by accident or design. Out of the 1671 sessions initiated, 1347 (81%) were from a new visitor to the application and of 695 cases entered, 85% were test cases, whereby the user explored the application by completing a report. We suggest that any deliberately fabricated reports are likely be reflected by multiple entries by returning individuals and/or a higher proportion of real to test cases. Of note, the potential for accidental or intentional entry of erroneous reports likely applies to many rare event registries, whether online or not, and whether voluntary or mandatory.

Although our local Ethics Board approved this study, given its international nature and novelty as a means of data collection, we sought the additional opinion of an ethicist (TD). The use of the Airway App for crowdsourcing to collect large datasets is probably best viewed as an observational study (where observational studies include case reports) and crowdsourcing can be seen as the collection of case studies on a grand scale. Ethically, observational studies are generally assumed to be low risk, since they are non-interventional. The Airway App appears especially low risk, since the data gathering does not appear to impose any burden on either the health professional performing the airway intervention, or the patient on whom it is performed. There is no researcher/clinician conflict, since the clinicians reporting the data are not also analysing it, and the data cannot be traced back to the patient.

However, one obvious ethical concern with the Airway App is the absence of patient consent for the inclusion of their case. Healthcare practitioners and researchers will be familiar with presumptions requiring patient consent for the use of their data [23]. However, there is broad international consensus on the conditions under which consent for the use of data may be waived [24–27]. Those conditions typically include requirements that: data collection and use is low risk; the benefits of the data use justify any risks of harm associated with not seeking consent; it is impossible in practice to obtain consent due to the quantity or age of the records; and obtaining individual informed consent would make the research impracticable. The Airway App seems to meet these conditions. It collects and uses non-identifiable data in ways which promise considerable advantage, with no or minimal risk to patients. Of note, the data from two large registries, NAP4 [10] and Danish Anaesthesia Database [22], also occurred after ethical review and without patient consent being deemed necessary.

In conclusion, in the words of Dr. Helen Link Egger [28], "*We've gone as far as we can with traditional research. Now we have the technology in our pockets that lets us go even further*." The Airway App collects and uses non-identifiable data in ways which promise considerable advantage. It provides minimal risk to patients and yet large numbers of events can be analysed in an anonymous fashion We have shown that the Airway App enables collection of data on rare airway events at a useful rate. The events reported so far have been reported in a manner that suggests they are discrete and genuine cases. The aggregated data are consistent with other similar registries. Further data collection with the Airway App provides the opportunity to collect a large international data set of eFONA cases whose analysis may provide useful information and new insights into this rare emergency treatment.

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