Journal of Clinical Anesthesia (2016) **31**, 106–110

Journal of Clinical Anesthesia

Original Contribution

Estimating the number of difficult airway carts needed in an operating suite: Resource planning without compromising patient safety☆

Chiedozie I. Udeh MD, MHEcon [a,*], **Belinda L. Udeh PhD, MPH** [b], **Jarrod E. Dalton PhD** [c]

[a] *Department of Cardiothoracic Anesthesiology, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195, USA*
[b] *Department of Outcomes Research, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195, USA*
[c] *Departments of Quantitative Health Sciences and Outcomes Research, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195, USA*

Received 14 August 2014; revised 27 July 2015; accepted 12 January 2016

Keywords:
Airway management;
Anesthesia;
Resource allocation;
Probability

Abstract
Study Objective: To determine the number of difficult airway (DA) carts required based on the number of anesthetising locations and patients risk of DA.
Design: Binomial distributions.
Setting and Patients: Various hypothetical settings and patient cohorts.
Interventions and Measurements: Binomial distributions were used to calculate the number of distinct combinations of DAs by number of anesthetising locations assuming an average risk of 10%. The 'at least' number of DAs was calculated using cumulative probabilities of having exactly two plus more than 2 DAs up to the total number of simultaneously started anesthetising locations *or* until the cumulative probability exceeds the 50% threshold, therefore being more likely than not.
Main Results: The probability of encountering concurrent DAs increases as the number of simultaneously started anesthetising locations increases. For at least 2 concurrent DAs, the probability first exceeds 50% at 17 locations. The corresponding thresholds for at least 3 and 4 concurrent DAs, are 27 and 37 locations respectively. The probability of at least 2 concurrent DAs will exceed 50% when approximately 17 anesthetising sites are started simultaneously and a 10% worst case risk is assumed.
Conclusions: With continuing resource constraints, proper planning of human and capital resources for DAs needs to be addressed without compromising patient safety. It is recommended that every block of 15–20 sites be equipped with a DA cart, that anaesthesia groups develop and rehearse DA algorithms with available equipment, and that preoperative anaesthesia clinics be used to identify DA therefore providing logistical leverage.

☆ Conflict of interests: The authors declare that they have no conflict of interest.

* Corresponding author at: Cardiothoracic Anesthesiology, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195, USA. Tel.: +1 216 444 2781; fax: +1 216 444 2536.
E-mail addresses: udehc@ccf.org (C.I. Udeh), udehb@ccf.org (B.L. Udeh), daltonj@ccf.org (J.E. Dalton).

http://dx.doi.org/10.1016/j.jclinane.2016.01.008
0952-8180/

1. Introduction

Management of the difficult airway (DA) can be challenging, especially if unexpected. The incidence of difficult intubation is estimated at 5.8% (confidence interval of 4.5%-7.5%) and the incidence of difficult mask ventilation is 2.4% [1,2]. However, because of non-standardized nomenclature, published estimates vary widely from 1.5% to 10% [3,4]. Definitions may include physical features, difficulty with mask ventilation, laryngoscopy or tube insertion, number of laryngoscopy attempts, experience level of the practitioner and whether intubation failed [3–5]. Failure to secure an airway poses a safety risk to patients plus economic consequences from prolonged anesthesiologist-controlled times and case cancellations [6–8]. Unfortunately predictive tests are not very accurate [5]. Consequently DA management algorithms continue to evolve and include steps requiring advanced airway devices such as supraglottic devices, video-laryngoscopes, fiberoptic bronchoscopes, and emergency tracheal access kits [9].

Most facilities have at least one DA cart containing advanced airway devices. Despite the proliferation of brands and models, no single device uniformly outperforms the others, because intubation success depends on patient characteristics and operator skill [5,10,11]. As such, there is no consensus on which exact devices should be included in DA carts [9]. Furthermore, these advanced airway devices are expensive. The acquisition cost of a DA cart with one selection from each of these device categories, in different sizes if available, exceeds $40,000. With only one anesthetizing location, only one DA cart is needed and with unlimited resources, every location would have a DA cart.

Intuitively, the probability of concurrent DAs increases with the number of simultaneously started anesthetizing locations. In most institutions, this would most typically pertain to first case starts of the day when multiple cases begin simultaneously. With differing case durations, subsequent case starts are naturally staggered, so the likelihood of concurrent DAs is lower. Patient safety being paramount, there should be sufficient carts to handle concurrent DAs. Given the cost of DA carts, the fact that some difficult airways are unanticipated, and the varying number of simultaneously started anesthetizing locations, how might the optimal number of DA carts be determined so as to balance patient safety and resource constraints? We have applied a binomial probability distribution of concurrent DAs to estimate how many DA carts are needed given any number of simultaneously starting anesthetics.

2. Methods

Our analysis is deterministic and relies on the following assumptions to define the probability formula.

- We assumed an additional DA cart would be needed for that number of simultaneously-started anesthetizing locations at which a preset threshold probability of concurrent DAs is crossed. As a decision threshold we selected that point at which there is a better than chance probability (i.e. exceeding 50%) of at least 2, 3, or 4 concurrent DAs.
- Recognizing the primacy of patient safety, we assumed a preference to err by having a surplus of DA carts rather than endure an adverse event because DA equipment is unavailable. Accordingly we assumed a broad definition for DA and adopted a conservative 10% incidence of DA for the base case analysis.
- We assumed that each patient's risk of having a difficult airway (denoted by the symbol p) is equal and independent of other patients' risks. This simplifying assumption allowed for expressing the overall probability of having b concurrent difficult airways among a set of s simultaneously started anesthetizing locations using the binomial distribution. Theoretically, although the probability p might be differentially expressed from patient to patient depending on certain predictive information, we felt that a single probability representing the average risk among all patients was sufficient for planning.
- Institutions with different case mixes would experience varying incidence of DAs. (For instance trauma centers or bariatric surgery centers would expect to have a higher proportion of patients with DAs). Recognizing this fact, we performed one-way sensitivity analysis by repeating the calculations using specified DA incidence of 1%, 2.5%, and 5%.

Specifically, the binomial distribution specifies that this probability is:

$$\Pr(b \text{ difficult airways in } s \text{ locations}) = \binom{s}{b} p^{b}(1-p)^{s-b}, \quad (1)$$

Where the factor, $\binom{s}{b}$, read "s choose b", represents the number of distinct combinations of b difficult airways among s locations. For instance, if there are b=2 concurrent difficult airways and there are s=3 rooms then, $\binom{s}{b} = 3$; the distinct combinations of locations with difficult airway are the first and second location, the first and third location, and the second and third location. This factor can be directly calculated as:

$$\binom{s}{b} = \frac{s!}{b!(s-b)!}$$

Where the factorial operator "!" is defined by, $s! = s(s-1)(s-2)\cdots(3)(2)(1)$.

Eq. (1) above represents the probability of *exactly* b difficult airways in s locations, but what is actually needed is the probability of *at least* b difficult airways. Conceptually then, the probability of at least two DAs, would equate to the cumulative probability having exactly two DAs plus the probabilities of having more than two DAs. Depending on the number of simultaneously starting anesthetizing locations, this would be the cumulative probability of *exactly* two