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ORIGINAL ARTICLE

Comparative Evaluation of Bain Circuit Versus Non-invasive Ventilation for Preoxygenation in Preventing Peri-Intubation Hypoxemia

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ABSTRACT

Introduction: Preoxygenation is a cornerstone of safe airway management, aiming to prevent hypoxemia during the apnoea associated with intubation. Efforts to optimize preoxygenation have led to the exploration of alternative techniques, such as non-invasive ventilation (NIV). The Bain circuit, a low-resistance modification of the Mapleson D system, is commonly utilized for its effcient gas delivery to support both spontaneous and controlled ventilation.

Settings and Design: Prospective observational study.

Methods and Materials: The aim was to compare the effectiveness of the Bain circuit versus NIV in preoxygenation to prevent peri-intubation hypoxemia. A prospective study was conducted among 40 subjects (20 in each of the NIV and Bain circuit groups) who were 18 years of age or older. Pregnant patients and those

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with diffculty in the airways, hemodynamic instability, and facial trauma were excluded. The lowest SpO_2 level achieved, the time to desaturation (SpO_2 < 90%), and the incidence of hypoxemia and adverse outcomes were noted in both groups and compared.

Results: The lowest SpO_2 level achieved was 88.0% and 83.0% in NIV and Bain circuit groups respectively (p <0.049). Incidence of hypoxemia was higher in the Bain circuit group than the NIV group (15.0% v 5.0%; p <0.049). Time to desaturation during intubation was found to be higher in the Bain circuit group. Two patients (10.0%) in the Bain circuit group and one patient (5.0%) in the NIV group developed aspiration pneumonitis during intubation.

Conclusions: Among adults undergoing tracheal intubation, preoxygenation with NIV resulted in a lower incidence of hypoxemia during intubation than preoxygenation with the Bain circuit.

KEYWORDS

• Non invasive ventilation • Bains circuit • Prospective study • Observational study • Emergency medicine

INTRODUCTION

Each year in the United States, more than 1.5 million critically ill patients undergo tracheal intubation.[1,2] During this procedure, 10% to 20% experience hypoxemia, particularly in emergency or intensive care settings, which is linked to a higher risk of cardiac arrest and mortality.[3–5]

Preoxygenation, administering supplemental oxygen before anesthesia induction, is a common strategy to improve oxygen reserves in the lungs and lower the chance of hypoxemia during intubation.[6,7] In most cases, this is done using a standard oxygen mask, which is easy to apply and, under optimal conditions, can deliver a fraction of inspired oxygen (FiO_2) of up to 100%. However, these masks lack the ability to provide positive airway pressure or ventilatory support, and in practice, due to room air mixing in from around the mask, the actual FiO_2 delivered may be significantly lower, sometimes around 50%.[8]

An alternative is NIV, such as bilevel positive airway pressure (BiPAP). This method uses a sealed mask and high gas flow to deliver nearly 100% FiO_2 while also providing both ventilation assistance and positive pressure. However, NIV takes more time to set up and may carry a heightened risk of aspiration during intubation[9,10] One study found that using noninvasive ventilation for preoxygenation was associated with a lower incidence of hypoxemia compared to an oxygen mask.[11] In contrast, a separate study reported no significant difference in outcomes between the two approaches.[12]

Another option is the Bain circuit, a semi-open breathing system commonly used in anesthesia.[13] It delivers high fresh gas flow, which helps flush out exhaled carbon dioxide and prevents rebreathing. The Bain circuit can also be adapted for preoxygenation in intubation, especially in controlled settings like the operating room. It is lightweight, easy to handle, and capable of delivering high concentrations of oxygen. However, it requires careful monitoring and proper flow settings to ensure patient safety and effective ventilation. While both (NIV) and the Bains circuit are established methods for pre-oxygenation before intubation in anesthesia, their comparative effectiveness in maintaining oxygenation and reducing the risk of hypoxia during emergency airway management remains uncertain; this study aims to directly compare NIV and the Bain's circuit to determine which method offers superior patient safety and oxygenation in the emergency setting.

MATERIALS AND METHODS

Institutional ethical clearance and informed written consent were obtained. Those meeting the inclusion criteria were randomized into two groups: Group A (preoxygenation using the Bain circuit) and Group B (preoxygenation using noninvasive ventilation). Preoxygenation was conducted for 3 minutes using 100% oxygen delivered at a flow rate of 10 L/min. Continuous monitoring of SpO_2 levels was

conducted using a pulse oximeter, beginning from the start of preoxygenation until the completion of intubation.

Outcome variables measured in this study were Hypoxia, Aspiration and Intubation attempts.

The following methods were used: Descriptive statistics (mean with standard deviation, frequencies, percentages), Chi square or Fisher's exact test of association. Anesthesia induction and muscle relaxation followed institutional protocols, and intubation was performed by experienced emergency physicians using a standard laryngoscope.

RESULTS

The study population had a mean age of 30.21 ± 4.32 years, with a relatively even gender distribution 57.1% males and 42.9% females in the Bain circuit group, and 42.9% males and 57.9% females in the NIV group (*Figure* 1). The gender distribution of the study population is shown in *Figure* 2. *Table* 1 presents the sociodemographic characteristics of the study population, with participants stratified into four distinct age groups. Most were aged between 21–35 years, comprising 57.9% (Bain circuit) and 42.1% (NIV). The older age group (>50 years) was exclusively in the NIV group (100%), while none were assigned to the Bain circuit. Hypoxemia was more common in the Bain circuit group (75.0%) compared to NIV (25.0%), with a statistically significant difference (p = 0.045) (*Table* 2).

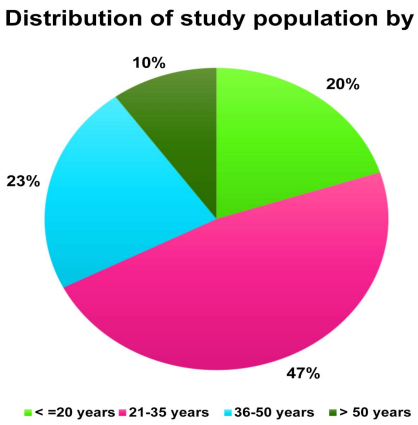

Figure 1: Distribution of study population by age

Aspiration events were not significantly different between the two groups (p = 0.548). Aspiration events were 2 (66.7%) in bains circuit and 1 (33.3%) in NIV groups. Regarding intubation attempts, most required only one attempt 12 (42.9%) in Bains circuit and 16 (57.1%) in NIV. Incidents of second attempts were more frequent in the Bain group (70.0%) than in NIV (30.0%), though not statistically significant (p = 0.338) (Table 2). Outcomes of Intubation is depicted in Table 3. The mean time from induction to intubation was slightly longer in the Bain circuit group (97.7 ± 6.7 seconds) compared to NIV (94.05 ± 7.8 seconds), but not statistically significant (p = 0.122). Median SpO_2 and FiO_2 at 24 hours were identical in both groups (SpO_2 = 97%, FiO_2 = 0.40) with p = 1.000. A statistically significant difference was observed in the mean lowest SpO_2 achieved, being lower in the Bain circuit group (83%) than in the NIV group (88%) (p = 0.049).

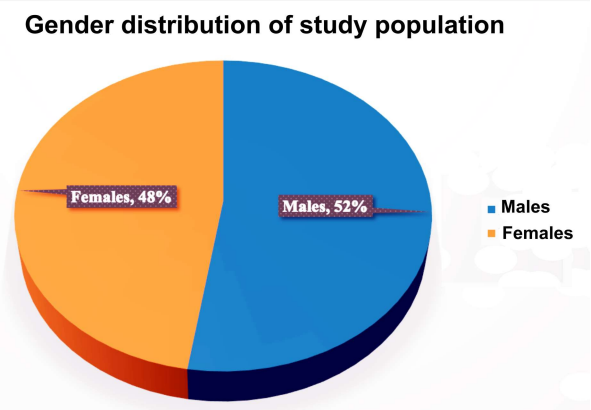

Figure 2: Gender distribution of the study population by age

Table 1: Sociodemographic details:

Sociodemographic details	Variables	Bain circuit	NIV	p value
Age (in years)	<=20	4 (50.0)	4 (50.0)	0.205
	21 - 35	11 (57.9)	8 (42.1)	
	36 - 50	5 (55.6)	4 (44.4)	
	> 50	0 (0.0)	4 (100.0)	
Gender	Males	12 (57.1)	9 (42.9)	0.342
	Females	8 (42.1)	11 (57.9)	

Table 2: Characteristics of Intubation procedure:

Variables		Bain circuit	NIV	p value
Hypoxemia	Present	3 (75.0)	1 (25.0)	0.045
	Absent	17 (47.2)	19 (52.8)	
Aspiration	Present	2 (66.7)	1 (33.3)	0.548
	Absent	18 (48.6)	19 (51.4)	
Intubation attempts	1	12 (42.9)	16 (57.1)	0.338
	2	7 (70.0)	3 (30.0)	
	3	1 (50.0)	1 (50.0)	

Table 3: Outcomes of intubation:

	Bain circuit	NIV	p value
Mean time from induction to intubation (seconds)	97.70 ± 6.7	94.05 ± 7.8	0.122
Median SpO_2 at 24 hours (%)	97.0	97.0	1.000
Median FiO_2 at 24 hours (%)	0.40	0.40	1.000
Mean lowest SpO_2 level achieved (%)	83.0	88.0	0.049

Table 4: Discussion

Author	Gibbs *et al*	Fong *et al*	Baillard *et al*	Present study
Year	2024	2019	2006	2024
Study type	RCT	Meta analysis	RCT	Prospective cross-sectional study
Sample size	1301	959	53	40
Results	Hypoxemia – 9.1% in NIV and 18.5% in Oxygen mask group	NIV better than COT and HFNC for pre oxygenation	Spo2: 98 ± 2 (NIV) and 93 ± 6 (bag valve mask)	Hypoxemia – 5% in NIV and 15.0% in Bain circuit group
Conclusion	Pre oxygenation with NIV better than oxygen mask	NIV is a safe and probably the most effective preoxygenation method	NIV is more effective at reducing arterial oxyhemoglobin desaturation	preoxygenation with non-invasive ventilation resulted in a lower incidence of hypoxemia

DISCUSSION

Preoxygenation is a critical step in the process of securing the airway, particularly in emergency and high-risk patients, as it significantly extends the safe apnea period during intubation. This study compared the effcacy of two commonly used techniques Bain circuit and Non-Invasive Ventilation (NIV) in preventing peri-intubation hypoxemia.

The findings from our prospective cross-sectional study, which involved 40 patients divided equally into two groups, indicate that preoxygenation using NIV was associated with a lower incidence of hypoxemia (SpO_2 <90%) during intubation when compared to the Bain circuit. Furthermore, patients in the NIV group exhibited higher minimum oxygen saturation levels and a longer time to desaturation, indicating more effcient oxygen delivery and improved alveolar oxygen reserves.

These findings are consistent with those reported in previous studies. For instance, Baillard *et al*. (2006) demonstrated that NIV improved preoxygenation in hypoxemic patients by enhancing alveolar recruitment and increasing end-expiratory lung volume. Likewise, Gibbs *et al*. (2024) demonstrated significant improvements in intubation outcomes with NIV compared to standard oxygenation techniques in their large, multi-center trial.[14] From a physiological standpoint, the effectiveness of NIV can be attributed to its ability to provide both positive end-expiratory pressure (PEEP) and augmented tidal volumes during spontaneous breathing, resulting in better maintenance of oxygenation. The Bain circuit, while effective in many anesthetic settings, may be less optimal in spontaneously breathing patients or those with compromised pulmonary function due to its reliance on passive oxygen flow without PEEP. Importantly, the adverse event profile favored NIV. Fewer patients in the NIV group experienced complications such as aspiration and hemodynamic instability, though these outcomes were not statistically analyzed in detail due to the small sample size. Nonetheless, this finding underscores the potential safety advantage of NIV in emergency airway management. While the study provides valuable insights, some limitations must be acknowledged: The sample size was relatively small (n=40), limiting the generalizability of the results. The study was conducted in a single center, which may introduce bias related to clinician experience and institutional practices. No subgroup analysis was performed to assess the impact of patient comorbidities or clinical status on preoxygenation effectiveness. Despite these limitations, the study supports the growing body of evidence that favors the

use of NIV over traditional methods such as the Bain circuit for preoxygenation, especially in high-risk and emergency scenarios.

CONCLUSION

This study compared the effectiveness and safety of the Bain circuit and non-invasive ventilation (NIV) techniques during intubation. While both groups had similar demographic profiles, a few important differences emerged. Hypoxemia was significantly more common in the Bain circuit group, and they also experienced a lower minimum oxygen saturation during the procedure. Although aspiration events and the number of intubation attempts did not differ significantly between groups, a trend toward more second attempts was noted in the Bain circuit group. Time to intubation and oxygenation levels at 24 hours post-intubation were comparable. Overall, the findings suggest that while both methods are viable, the NIV approach may offer better oxygenation and fewer hypoxemic episodes during intubation, potentially making it a safer choice in clinical practice in.

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