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Effects of vacuum suctioning and strategic drape tenting on oxygen concentration in a simulated surgical field☆

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Abstract

Study objective: To investigate the isolated and combined effects of vacuum suctioning and strategic drape tenting on oxygen concentration in an experimental setting.

Design: Experimental.

Setting: Clinical simulation center of a university-affiliated hospital.

Participants: Mannequin simulation of a patient undergoing facial surgery under sedation anesthesia. Supplemental oxygen was delivered via nasal cannula.

Interventions: Vacuum suctioning and strategic drape tenting.

Measurements: The experimental trials entailed measuring oxygen concentration around the nasal cannula continuously either in the presence or absence of a standard operating room vacuum suction system and strategic tenting of surgical drapes. The primary outcome was the time required for oxygen concentration to reach 21%.

Main results: In the control group (without suction or strategic tenting), a mean time of 180 seconds elapsed until the measured oxygen concentration reached 21% after cessation of oxygen delivery. Use of a vacuum suction device alone (110 seconds; $P < .01$) or in combination with strategic tenting (110 seconds; $P < .01$) significantly reduced this time. No significant benefit was seen when tenting was used alone (160 seconds; $P < .30$).

Conclusion: Use of a vacuum suction device during surgery will lower local oxygen concentration, and this in turn may decrease the risk of operating room fires. Although strategic tenting of surgical drapes has a theoretical benefit to decreasing the pooling of oxygen around the surgical site, further investigation is necessary before its routine use is recommended.

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1. Introduction

Each year, there are approximately 550 to 650 cases of operating room fires reported in the United States [1]. Given that more than 85 million surgical procedures are performed annually [2,3], operating room fires are relatively rare events. Approximately 10 to 20 of these fires result in significant patient injury [4], and occasionally, fatalities have been reported [5]. The personal, financial, and medico-legal ramifications of operating room fires are devastating, and therefore, these occurrences are considered preventable "never events" by the National Quality Forum [6].

Despite growing awareness of the sequelae of operating room fires [7], more action is needed to delineate associated risk factors and preventative measures. Surgical fires are caused by a necessary "fire triad" composed of an ignition source, oxidizer, and fuel [8]. Although many materials in the operating room are combustible, oxygen serves as the oxidizer in more than 95% of operating room fires [9]. Approximately 3 of 4 reported surgical fires implicate the pooling of oxygen beneath surgical drapes or within the operative site [5]. Recommended measures to mitigate oxygen pooling include the use of a vacuum suction to decrease ambient oxygen concentration [1,10] and reduction of oxygen beneath surgical drapes through purposeful and strategic drape tenting techniques [11-13]. Both of these interventions aim to reduce the available oxidizer in the surgical field and can be readily performed by the vigilant surgeon to help reduce the risk of an operating room fire.

In this study, a realistic mannequin model was used to examine how vacuum suctioning and strategic drape tenting, alone or in combination, can facilitate dissipation of oxygen concentration during an operation involving the head and neck region performed under sedation anesthesia.

2. Materials and methods

Experiments were conducted at the University of Michigan Clinical Simulation Center using a "Little Anne" mannequin (Laerdal, Wappingers Falls, NY) equipped with integrated oral and nasal passages. We fitted a standard nasal cannula (Covidien, Minneapolis, MN) widely available for clinical use onto the mannequin in a typical fashion with the prongs inserted within the nostrils. Oxygen flow was supplied from a pressurized oxygen tank at 6 L/min. Oxygen concentration was measured continuously using a Pyroscience FireStingO_2 meter (Aachen, Germany). According to the manufacturer, the meter is capable of reading oxygen concentrations between 0% and 100% with an accuracy of ± 0.02% and a response time of less than 1 second. A single oxygen sensor was placed 1 cm from the nasal cannula to measure the ambient oxygen concentration (Fig. 1). Testing occurred with the mannequin in a supine position on a hospital gurney within the simulation center. Paper operative drapes (3M, St Paul, MN) were placed over the bridge of the mannequin's nose and were allowed to fall downward over the cephalic end of the table. Once a stable sensor recording of 100% oxygen concentration was achieved, the supplemental oxygen supply was discontinued, and the timer was started. Subsequently, oxygen concentration was recorded every second by the oxygen sensor until a stable level of 21% (fraction of oxygen in ambient air) was reached.

Vacuum suctioning was performed with a widely available Yankauer catheter (AG Industries, Saint Louis, MO) connected via tubing to a Boehringer Suction Regulator (Phoenixville, PA). The tip of the suction catheter was placed approximately 5 cm from the nasal cannula (Fig. 1) and was secured to the mannequin. Continuous vacuum suction was set to 400 mm Hg, a pressure available in all University of Michigan Health System operating rooms. Strategic tenting of the surgical drapes was achieved by lifting the cephalad corners of the drapes and attaching them to poles to reduce oxygen pooling and facilitate the flow of oxygen away from the surgical site (Fig. 2). *Tenting* is a term that has been previously used in the literature and refers to securing the ends of surgical drapes to intravenous poles during facial surgery [11].

Experimental trials were then conducted under 4 different conditions: (1) without suction or strategic tenting (control), (2) with suction only (group S), (3) with both suction and tenting (group S + T), and (4) with tenting alone (group T). To reduce selection bias, the experimental condition was randomly selected during the investigation. Oxygen concentration was measured continuously during each trial, and a total of 3 trials were performed for each experimental condition. The primary outcome was the amount of time necessary for oxygen concentration to drop from 100% to 21%. Measurements were averaged at each time point within each group. Outcomes were compared by performing a linear regression model using the study groups as the experimental variable and time as an adjustment variable. Statistical significance was set at $P < .05$.

3. Results

The rates of oxygen dissipation measured during the experiment for each study group are depicted in Fig. 3. Trials performed without vacuum suctioning or strategic drape tenting (control) demonstrated an average duration of 180 seconds for oxygen concentration around the surgical site to drop to 21% after the source was shut off (Fig. 4). In contrast, when the vacuum suction was used (group S), the mean time before oxygen concentration reached 21% was reduced to 110 seconds ($P < .01$). Similarly, when strategic drape tenting was used in conjunction with suctioning (group S + T), a mean time of 110 seconds elapsed before oxygen concentration reached the 21% threshold. However, when strategic drape tenting was used alone without the effects of vacuum suctioning (group T), the mean time was somewhat lower