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Surgical plume and its associated hazards to perioperative staff: A review of current standards for practice and risk management

Abstract

Surgical plume poses a risk to perioperative nurses and the perioperative team as a whole, as well as the operative patient. Surgical plume contains various hazardous components which pose multiple health risks to the perioperative staff who are exposed to it. Further research is required in order to definitively understand the risks to perioperative staff from long-term exposure to surgical plume and to advance current policies and procedures. The current practice standard on surgical plume management from the Australian College of Perioperative Nurses (ACORN) sets out methods of reducing these risks. However, this standard's utility in practice and barriers to its implementation lead to ongoing unnecessary plume exposure. Through adhering to current practice standards and educating perioperative nurses, the risks posed by surgical plume can be mitigated. Thorough education on this topic will empower nurses to advocate for their safety and the safety of their patients, leading to the reduction of surgical plume exposure.

Keywords: surgical plume, surgical smoke, perioperative nurse, operating theatre, ACORN standards

Introduction

According to the Nursing and Midwifery Board of Australia (NMBA) it is the responsibility of all registered nurses (RNs) to provide safe and quality care; this includes ensuring a safe care environment for patients and a safe work environment for staff.[1] Registered nurses in Australia are governed by the standards for practice defined by the NMBA in order to ensure quality health care provision. Perioperative nurses are further guided by the Australian College of Perioperative Nurses (ACORN) which aims to advance the quality and safety of the care provided within the perioperative environment.

Governing bodies provide a professional framework for legally and ethically accountable practice; this, combined with practice standards, protects both patients and health care professionals. There are many health and safety risks within an operating theatre and perioperative nurses must be educated about these issues and comply with regulations in order to reduce adverse incidents.[2] This paper will discuss the safety issues relating to surgical plume in the operating theatre and how this hazard impacts perioperative nurses and the perioperative team as a whole as well as patients receiving care. It will clearly define surgical plume, its dangerous components and describe in detail the health risks of recurrent plume exposure using the most recent research available. The ACORN standards relating to this safety issue will be outlined and their utility to practice analysed.

Discussion

Surgical plume is the smoke or vapour generated when biological tissue is disrupted by energy-based devices. When an electrosurgical device is used, it causes the rupture of cellular membranes and releases the vaporised intracellular contents, which may include visible or invisible particulates, gas and smoke.[3] Surgical plume is primarily water in the form of steam, with approximately five per cent of the plume comprising cellular debris which can include carcinogens, toxins, blood, bacteria, viruses and tissue particles.[4] As this plume is aerosolised it may spread throughout the operating theatre with consequent risk to both staff and patients of inhaling plume and its associated toxins.

The risks associated with surgical plume have been widely researched for almost 40 years in an attempt to establish proof of transmission of malignancy, viruses and respiratory illnesses in perioperative staff and patients alike.[5] Despite this there is still a deficit in conclusive evidence of causation and more research, specifically longitudinal studies, are required. In recent years the majority of research into surgical plume has been investigating the potential transmission of COVID-19 through this route.[6] While there is a theoretical risk of transmission, this still remains to be proven.[6] Research on surgical plume thus far has effectively led to advancements in technologies, increased practice standards and protocols for safe use of electrosurgical equipment and plume evacuation devices.

Energy-based devices that produce surgical plume include electrosurgical units (such as used in diathermy), ultrasonic devices, radiofrequency devices and lasers.[3] Lasers involve a beam of intense directional light produced through electromagnetic radiation which is then targeted at the operative tissue.[7] Radiofrequency and ultrasonic surgical devices, on the other hand, denature proteins via use of high frequency vibrations to both cut and seal tissues. The most frequently used energy-based surgical devices are those used in diathermy where electrical current is used to achieve surgical hemostasis and as a method of surgical dissection.[4] Diathermy electrosurgery devices can be either bipolar or monopolar. Bipolar devices deliver current via two electrodes, the tips of forceps which grasp the intended operative tissues.[8] Monopolar devices deliver current via a single active electrode that comes into contact with the operative tissue.[8] The electrosurgical devices described all produce surgical plume either through tissue disruption, vaporisation or burning.[4]

The physical particles within plume can range in size from 0.01 micron to more than 200 microns. Studies have shown that particles less than 0.3 microns in size can bypass the lungs' normal filtration system and reach the bronchioles and alveoli.[9] These particles can deposit in the alveoli and incite inflammatory changes, resulting in pneumonia, congestion and bronchiolitis, and aggravate pre-existing respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD).[9] Furthermore, once particles reach the alveoli there is a risk of haematogenous and lymphatic spread of toxins, carcinogens and pathogens throughout the body.[5] Prolonged exposure to surgical plume can extend to risks beyond the respiratory system, increasing risk of developing cardiac disease, neurogenerative disorders, such as Alzheimer's and Parkinson's disease, and various forms of cancer.[5] Due to the toxins and carcinogens it contains, inhaling surgical plume has often been equated to the health hazards of smoking cigarettes. One study postulated that the smoke produced in an operating theatre in one day was the mutagenic equivalent contained in almost 30 cigarettes, while another study found that the smoke produced during just one surgical operation could equal the same toxin exposure as passively smoking 20 cigarettes.[10]

Surgical plume has been found to contain live viruses which have the potential to be transmitted when inhaled by the perioperative team.[3,8] Studies have shown that viruses such as human immunodeficiency virus 1 (HIV-1), human papillomavirus virus (HPV) and hepatitis B virus (HBV) have been detected within the aerosolised vapors of surgical plume.[11] Currently there is only evidence of HPV being transmitted via surgical plume; however, this raises valid concerns regarding the possibility of further virion transmission.[6]

While there is an association between exposure to aerosolised HPV particles in surgical plume and development of cancers, definitive evidence of causation is still yet to be determined. A 2017 study discussed the correlation of prolonged exposure to surgical plume containing high-risk HPV and the development of tonsillar carcinoma in two gynaecologists.[12] These surgeons did not have additional risk factors for developing tonsillar carcinoma thus minimising confounding factors; it is hypothesised that their ongoing exposure to surgical plume while performing loop electrosurgical excision procedures and laser ablation was the cause for their cancer developing.[12] Unfortunately, this research could not definitively conclude causation, longitudinal research is required in order to prove an indisputable link between surgical plume and the development of malignancy.

Due to COVID-19 the use of N95 masks in clinical settings was temporarily mandated in most health care organisations around Australia. Interestingly, an unintentional benefit of this is that staff are better protected from surgical plume when wearing N95 masks compared to standard surgical masks. When fitted properly, N95 masks provide protection against penetrating aerosols up to 0.3 microns while standards surgical masks, although they shield from infectious droplets, offer little protection against aerosols.[13] This added protection against surgical plume is beneficial to staff although particles below 0.3 microns still pose a danger,[9] as previously explained. According to ACORN's Surgical plume standard, masks must never be used as a first line of defence against surgical plume.[14] However, N95 masks may prove to be a beneficial second line defence, highlighting a potential area of research which could lead to change in policies.

It is ACORNs position that patients and team members must be protected from surgical plume and its associated hazards. The ACORN Surgical plume standard predominately focuses on personnel operating machinery properly and following procedures, as well as highlighting perioperative nurses' duty of care to ensure a safe theatre environment.[14] According to this standard, perioperative nurses and other theatre personnel must use evacuation devices of an appropriate standard and check evacuation systems to ensure they are operating effectively.[14] Evacuation systems must be chosen based on risk assessments that consider the procedure to be performed and the expected volume of surgical plume. Personnel should confirm proper filtration systems are in place and that filters are disposed of in accordance with procedures for blood-borne pathogens.[14]

The ACORN Surgical plume standard clearly outlines how to best manage surgical plume and stipulates that health service organisations must also play a role in reducing this hazard. The standard suggests this can be accomplished through development of facility policies and procedures, practice standards and models to monitor compliance.[14] According to the standard, health service organisations have a responsibility to educate their staff about the hazards associated with surgical plume, and maintain up-to-date policies and procedures to guide staff in their practice of surgical plume management.[14]

The *National Safety and Quality Health Service Standards* (NSQHS Standards) 'Clinical governance' standard states that health service organisations have a duty to act on and reduce risks which impact both their workforce and patients.[15] Furthermore, health service organisations have a duty to monitor the effectiveness of risk management solutions and act to improve these systems as necessary.[15] The NSQHS Standards and the ACORN Standards both demonstrate the responsibility of health service organisations to have management plans in place and work to reduce the risk of staff being exposed to hazards such as surgical plume.

Education about the risk of surgical plume and monitoring compliance is arguably the most important aspect of ACORN's Surgical plume standard, as staff exposure to surgical plume is often associated with staff reluctance to implement the evacuation systems available. This is believed to be due to anxiety about using new technology without proper education, lack of understanding about the risks of exposure to surgical plume, and proceduralists refusing to use evacuation systems.[5]

In the absence of evidence-based education and structured training from educators, personal beliefs and opinions can prevent proper procedures from being followed. A lack of monitoring of compliance by educators and management results in ineffective use of or refusal to use smoke evacuation equipment; in turn, this is reinforced as normal practice. Policies and procedures are of little value without guided implementation or monitoring of staff compliance. Without proper education about the risks of surgical plume and its dangers, perioperative nurses are not equipped to advocate for their own safety, the safety of other staff or that of their patients.

If available evacuation systems are not properly used, not only are expensive resources wasted but personnel are also exposed to an avoidable health hazard. There are four main aspects to effective smoke evacuation: strength of the suction used, diameter of the suction tubing, volume of surgical plume and distance from the site of plume creation.[5] These aspects must be balanced with practicality as, ideally, smoke evacuation should not be disruptive to the surgery performed. Crucially, smoke evacuation systems must be not only efficacious but also easy to use so they are used effectively by the surgical team. Studies have shown that extraction devices used one inch from the site of plume creation can be 99 per cent effective; when devices are three inches from the desired site this effectiveness drops to only 53 per cent.[5] This fact highlights the importance of thorough education and training in the proper use of these devices. If they are used incorrectly their effectiveness is greatly diminished and surgical personnel will likely suffer from plume exposure.

Conclusion

There is evidence that surgical plume not only contains harmful toxins and carcinogens, but may also carry body fluids, bacteria and viruses which are then inhaled by staff.[4] There are substantial protocols, regulations and education programs associated with bloodborne pathogen transmission which are strictly enforced to protect health care staff. However compulsory safety procedures and staff education seem to be significantly lacking when it comes to surgical plume exposure. This needs to change in order to effectively protect perioperative staff and patients from significant health hazards. When staff are properly educated about the risks associated with surgical plume they are empowered to make changes to their practice and use smoke evacuation systems.[5] This highlights the need to make safe management of surgical plume a priority and provide education about this topic to all members of the perioperative team.

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