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*Original study*

# Fire in the operating room, a hot topic?
# Guideline development for operating room fire incidents by a literature review, semi-structured expert interviews and a qualitative, descriptive, anonymized cross-sectional study

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## *Abstract*

***Background:*** **The operating room (OR) is a high-risk environment which necessitates preparedness for potential life-threatening incidents, such as fulminant fires.**
**Existing protocols lack specific guidelines for anesthesiologists regarding emergency evacuation, and steps to be undertaken when leaving patients under anesthesia.**
***Objectives:*** **This research aimed to assess the anesthesiologists' preparedness to respond to fulminant fires in the OR and propose a safe to use guideline to optimize a patients' chance of survival while minimizing the risk of awareness.**
***Design:*** **Methods included a literature study, multi-disciplinary expert interviews (variant Delphi method), and a qualitative, descriptive, anonymized cross-sectional study in a select sample by means of a survey distributed amongst the anesthesiologists and residents working in the Flemish university hospitals. As such, 297 anesthesiologists and residents were addressed of which 64 participated, equal to a response rate of 21,5%.**
***Results:*** **Results indicated inadequate preparedness, with less than half considering crucial measures during emergency evacuation without the patient such as reducing the fraction of inspired oxygen (FiO2) (49.1%), deepening anesthesia (49.1%) or covering patient and ventilator with fire blankets (29,1%). Only 17.2% considered all three critical steps. Despite awareness of risks in the OR, only 36% could identify three specific risk factors. Self-reported confidence and perceived knowledge increased after guideline review by the participants.**
***Conclusions:*** **At this point research amongst Flemish anesthesiologists (and residents) suggests there is insufficient preparation for managing fulminant OR fires. The proposed guideline, addressing gaps in knowledge and actions, enhances readiness.**
**These critical steps, when implemented, can maximize survival chances during an incident. Future efforts should focus on widespread guideline implementation and ongoing training, besides further and more thorough research regarding this topic.**

***Keywords:*** **Fires, operating rooms, guideline, disaster planning, emergency response plan.**

*The content of this article has been presented at the thesis defense of the Postgraduate Degree of Disaster Management and at the public proclamation of the Postgraduate after winning the award of 'Best thesis 2023'.*
*Additionally, some results were presented during lectures given for various anesthesia services in Flanders.*
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*Ethics:Approval for this study was obtained from the ethics committee (chairman Prof. Dr. P. Michielsen) of the Antwerp University Hospital on June 28, 2022, under reference number 2022-3572. The study was conducted following the principles outlined in the Declaration of Helsinki. Survey participants were informed about the study's objectives and their right to withdraw from the study at any time without consequences. Additionally, neither of the investigators had any conflicts of interest to report.*

## Introduction

### *Incidence of operating room fires*

Fire incidents in the operating room (OR) are not rare occurrences. According to various studies, approximately 650 surgical fires leading to patient harm or death are reported annually in the United States (US) and suggest nearly four times as many near-fire incidents[1-4]. However, there is some variance in these numbers, with the Emergency Care Research Institute (ECRI) suggesting a lower estimate of around 100 annual surgical fires in the US5 (https://www.ecri.org/press/ecri-institute-announces-new-initiative-to-extinguish-surgical-fires)

In 2019, over 6.5 million surgeries were performed in the US, averaging 1 in 10 to 60 thousand surgical fire incidents resulting in patient harm or death6. Notably, legal actions against anesthesiologists and surgeons due to OR fires with patient injuries show an increasing trend in the US7.

In the United Kingdom (UK), around 500 hospital fires are reported annually, leading to over 650 injuries and 17 deaths over a decade8. At least three of these fires necessitated the complete evacuation of critical care services (ER/ICU) or the OR9. Remarkably, the number of patients affected by OR fires approaches those subjected to wrong-side surgery, yet assessing the fire risk is not a mandatory part of the safe surgery checklist[3,4,7] (https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.zorg-en-gezondheid.be/sites/default/files/2022-04/Eisenkader%2520operatiekwartier%2520revisie%2520april%25202022.docx&ved=2ahUKEwjn1_mf5ZmGAxWoTKQEHVcfCTkQFnoECA4QAQ&usg=AOvVaw0f2VUrNkD82EPRy42_0j73).

Despite the frequency of these incidents, there is a lack of awareness among healthcare personnel[3,7-10]. In Belgium, for instance, no central registration tool exists for reporting fire incidents in the OR, nor a legal requirement to do so. This is despite documented fire incidents in critical care areas (ER/ICU/OR) in different Flemish hospitals over the past decades, suggesting a need for greater attention to this issue (https://slideplayer.nl/slide/10352242/, https://www.despecialist.eu/nl/nieuws/brand-in-az-maria-middelares-gent-onderzoek-oorzaak-loopt-werking-spoeddienst-hervat.html).

While there have been full-scale fire drills in multiple Flemish OR's, the outcomes and lessons learned from these drills do not seem to be publicly accessible (https://www.azsintmaarten.be/nieuws/az-sint-maarten-zet-op-veiligheid-met-brandoefening-het-operatiekwartier#:~:text=AZ%20Sint%2DMaarten%20zet%20in%20op%20veiligheid%20met%20brandoefening%20in%20het%20operatiekwartier&text=Zaterdag%2018%20november%20evacueerden%20medewerkers,brandoefening%20in%20AZ%20Sint%2DMaarten).

Anesthesiologists, accustomed to working in critical care services where situations can quickly become life-threatening, often rely on established guidelines for managing emergencies such as airway fire incidents[11]. However, guidelines regarding emergency evacuation procedures, particularly when leaving patients under anesthesia behind, are lacking.

### *OR fires as high impact, low-probability events*

The OR presents a unique environment where the risk of fire is heightened due to the continuous presence of the fire triangle (oxygen, fuel, ignition)[1,2,9]. Extensive real-life experience dealing with OR fire incidents is rare, akin to malignant hyperthermia, yet knowledge of fire management is essential for anesthesiologists[9]. As such, OR fires can be categorized as high-impact, low-probability (HILP) events as defined by qualitative risk assessment tools used in risk management[12]. These HILP risks pose a specific challenge for policymakers, but just as much for hospitals (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl3-2022-drs-01-02).

Although conclusive evidence linking simulation training and protocol adherence to a survival benefit in these situations is lacking, numerous studies demonstrate that preparedness through training and clear guidelines improves management and response effectiveness[1,5,8-10,13-15]. Evaluations of hospital fire incidents and simulations often reveal a lack of communication, preparation, and practice. All of which can directly contribute to avoidable deaths, and as such can be qualified as a factor in incident outcomes[10,13,15-17].

### *Management of type 1a/b and type 2 OR fires*

In 2022, The (EU) Disaster Resilient Society stressed the importance of preparedness for HILP events (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl3-2022-drs-01-02). The Joint Commission International (JCI), frequently used in Belgium for setting the standard of quality patient care, recently approved some revisions regarding hospital fire drills conducted as part of their hospital accreditation program (https://

www.jointcommission.org/-/media/tjc/documents/standards/prepublications/hap_ec_edits_july_2022.pdf). These new requirements were implemented in July 2022. Amongst other recommendations, they stressed the need for prevention, drills, and the implementation of action plans1 (https://www.jointcommission.org/-/media/tjc/documents/standards/prepublications/hap_ec_edits_july_2022.pdf).

Differentiating between types of OR fires based on their origin and severity is crucial for effective management. We propose a new coding system to categorize OR fires, distinguishing between those originating from the patient (Type 1) and those from the environment or equipment (Type 2)[3].

Type 1 OR fires can be subdivided into Type 1a and 1b.

Type 1a OR fires are airway fires, often well described in literature and guidelines, follow a different management strategy, and were not further investigated in this study[3,11]. Most OR fires involve surgeries above the diaphragm, mostly airway surgery and ignition can most often be attributed to electrocautery[3,7].

Type 1b OR fires include all patient fires not starting as an airway fire, most often seen in emergency surgery. Even the correct management of type 1 OR fire incidents can result in patient harm or in the worst case even lead to the patient's demise. This can either be secondary to the type of fire, for example due to an immediate compromise of the patient's airway. Or due to the need for managing the fire before being able to perform time-critical lifesaving surgery.

Type 2 OR fires encompass fires in the OR originating from infrastructure or equipment. When a type 2 OR fire is mentioned, the existing literature mainly revolves around evacuation and extinguishing options[11,18]. This leaves unanswered what to do in the case of an OR fire where the patient cannot be evacuated. This might be due to the complexity of some procedures and the setup of the patient and surgical equipment, as witnessed in the 2006 Twenteborgziekenhuis OR fire (Almelo, Netherlands), leading to the unfortunate death of a patient (https://onderzoeksraad.nl/wp-content/uploads/2023/11/rapport_twenteborg.pdf).

Type 1 OR fires are more common than Type 2 OR fires and are usually a well-known risk among anesthesiologists, leading to awareness and explaining the existing guidelines on the management of Type 1 OR fires[3,7,11]. Most of these guidelines are based on basic principles (material properties, fire dynamics, physics) and expert opinions since it is impossible to perform randomized double blinded trials[11]. As mentioned, besides the differentiation between what is on fire (Type 1 (a/b) versus Type 2 OR fire incidents), a differentiation needs to be made regarding incident severity. An OR fire incident can either be controllable (C) or uncontrollable (UC).

Virtually all OR fires are preventable and usually start C, meaning there is time to subdue the event and limit the disastrous effects[3]. This is most often seen in Type 1 OR fires.

UC fires are considered unmanageable, often necessitating staff evacuation while leaving the patient behind. The main goal is to save as many lives as possible. This is mostly seen in Type 2 OR fires or in poorly managed Type 1 OR fire incidents.

### *Aim of the study*

The overall aim of this study is to address the gap in guidelines for anesthesiologists' actions in scenarios where patients are left in fulminant fires while the medical staff evacuates.

Firstly, the study seeks to assess the current level of preparedness among Flemish anesthesiologists and residents in responding to Type 2 OR fires, hypothesizing a knowledge gap among anesthesiologists, given the limited attention OR fires receive in standard anesthesia references.

Additionally, the study aims to propose an evidence-based guideline for managing such fires, prioritizing provider safety, optimizing patient survival chances, and minimizing awareness risks. The guideline should be integrable in the hospitals' emergency response plan. Noteworthy is that the provided guideline does not fit the needs for a disaster recovery plan.

## Materials and methods

### *Ethics*

Approval for this study was obtained from the ethics committee of the Antwerp University Hospital on June 28, 2022, under reference number 2022-3572. The study was conducted following the principles outlined in the Declaration of Helsinki. Survey participants were informed about the study's objectives and their right to withdraw from the study at any time without consequences. Additionally, neither of the investigators had any conflicts of interest to report.

### *Study design*

Firstly, a literature review was conducted, followed by a variant Delphi method with a semi-structured expert interview. This process was used to formulate a preliminary guideline.

Subsequently, this guideline was evaluated in a qualitative, descriptive, anonymized cross-sectional

study using a survey administered to a selected sample of the research population.

Given the lack of descriptive literature, no a priori power analysis was conducted.

The proposed guideline, formed by literature review and expert opinion, was integrated into the survey, that allowed for free-text feedback (non-limitative, open ended response possibility). This feedback was used to optimize the guideline to meet the criteria of provider safety, maximize chances of survival, minimize awareness risk, and align with the current evidence, while remaining implementable in daily practice.

### *Literature*

A two-part literature study was undertaken in the period of May to July 2022, to assess anesthesiologists' preparedness and to explore existing knowledge for guideline creation.

We conducted a PubMed search using relevant keywords such as fire, operating room, and evacuation, using the Boolean operator 'AND'.

To map the level of preparedness, the following elements were used in the same way: fire, operating room, and preparedness.

This yielded 19 search results for the evacuation query, published between 1976 and 2022. For the preparedness query, 5 articles were found, published between 2004 and 2010.

The summaries of the articles, available in Dutch, English, or French, were evaluated for relevance. Three articles were retained as relevant regarding evacuation, only one offering full access. Additionally, an applicable guideline from the Association of Anaesthetists of Great Britain and Ireland was found through the snowball method (reference found in one of the used articles).

Of the 5 articles found regarding preparedness, one article was considered relevant and had full access. Through the snowball method (cf. supra), three more relevant articles were found, one of which had full access (search string, cf. supplementary material 1 - See QR).

For the articles without full access (journals or database not accessible by the University of Antwerp), information available in the abstracts was utilized.

### *Variant Delphi method*

Given the exploratory nature of this research and the urgency for an implementable guideline, a variant Delphi method was used.

A heterogenous and multidisciplinary expert panel was established, comprising diverse disciplines including anesthesiology, burn center, emergency medicine, fire brigade, military, hospital emergency coordination and biomedical ethics (list of experts, cf. supplementary material 2 - See QR).

For each discipline, an expert was contacted either directly or via a large and well-established institution (e.g. university, fire brigade). If the addressed experts were willing to assist in the research, they were subjected to either an online or a live semi-structured interview.

First, an explanation was given regarding the research and its objectives. Any questions or uncertainties were clarified with the expert. Then they were asked to share their perspectives and essential considerations for OR fire guidelines development.

Specific questions arising from each interview were addressed and feedback was incorporated into the guideline draft. Finally, discipline-specific questions arising from the preceding literature review were also incorporated.

Some experts spoke from their respective positions for different disciplines as they are active in multiple areas. Their overlap in expertise across disciplines was considered valuable in the research, as they brought an integrated perspective on the subject matter.

Following all interviews, a guideline was drafted and sent back to each expert for initial feedback. Adaptations were made, if necessary, before inclusion in the survey.

### *Survey*

The survey targeted Flemish anesthesiologists and residents, distributed through anesthesia secretariats of four Flemish university hospitals (Antwerp University Hospital, Brussels University Hospital, Ghent University Hospital, and Leuven University Hospital).

The secretariats were asked to provide the number of eligible coworkers in their respective departments, allowing the calculation of a response rate.

Survey responses were collected between the 12th of January 2023 and the 17th of February 2023 with a reminder sent two weeks after the initial survey opening. Descriptive statistics were used to analyze the survey results, using SPSS 27 provided by the University of Antwerp (survey, cf. supplementary material 3 - See QR).

## Results

Out of 297 eligible residents and staff members, 64 completed the survey, resulting in a response rate of 21.5%. Following the survey, a maximum margin of error within the selected sample was calculated. With no pre-existing data available, p

was conservatively set at 50%, resulting in a margin of error of 12.25% for an infinite population. After correction within the finite selected sample, this gives a maximum margin of error of 10.87%, which is considered relatively wide.

Residents represent 57.8% of the total number of respondents. Among the staff member respondents, a majority of 90.6% reported having less than 21 years of work experience, including the residency training.

When inquiring about experience with OR fires, 54 respondents (84.4%) indicated they had no prior experience. Four respondents (6.3%) had experienced fires in an OR without the need for evacuation. None of the respondents had experienced a fire in the OR where evacuation was necessary. Additionally, only 7 respondents (11%) had undergone simulation training regarding OR fires. Only three of those simulations included an evacuation.

Although the small sample size precludes statistically significant conclusions, it is noteworthy that 2 of the 3 respondents who received specialist training abroad, had experience with simulation training regarding OR fires. Whereas this experience amongst colleagues who received their specialist training at one of the Flemish university hospitals varied between 0 and 13.3%. This observation highlights the need for further investigation into potential disparities in simulation training provision between foreign and Flemish training centers.

A majority of respondents (93.8%) expressed interest in the topic of fire in the OR. Over 9/10 of the respondents (90.6%) found it to be a relevant topic for their job. Moreover, almost 4/5 of the respondents (78.1%) indicated a desire to participate in simulation training on fire in the OR.

Over half (56.3%) of the respondents have little to no confidence in their ability to respond to a fire in the OR.

However, following the guideline, 59.35% indicated their self-confidence has increased, with

82.8% reporting a strong increase in knowledge about the necessary actions.

When exploring the awareness of risk factors related to fire in the OR, it is noticeable that 60.9% of the respondents is aware of the high-risk environment they're working in. However, just over 1/3 of the respondents (36%) can easily list more than three risk factors.

Investigating the instinctive course of action during an OR fire, respondents were asked to briefly write down their course of action, summarizing the priorities for maximizing patient survival, minimizing risk of awareness and being safe for the health care providers.

The answers were categorized so that similar responses could be taken together for analysis.

From the literature and expert interviews, we found that there are three crucial elements that can contribute to the proposed objectives of safety, survival chances, and risk of awareness. These elements are reducing the fraction of inspired oxygen (FiO2), deepening the anesthesia, and covering the patient, breathing tubes & ventilator with fire blankets.

Less than half of the respondents (49.1%) mentioned reducing the FiO2. An equal number of respondents thought about deepening the anesthesia, while only 29.1% indicated they would cover the patient with a fire blanket. Mentioning all three essential steps in their course of action for managing an OR fire incident was only done by 17.2% of the respondents.

It is also noteworthy that 3.6% of the respondents chose to increase the FiO2 to 100% and 3.6% of respondents decided to decrease the depth of anesthesia.

A large majority of 92.25% find the proposed guidelines relevant.

Of the respondents, 57 (89.05%) indicated they would consider using the guidelines in their own institution.

Respondents were given the opportunity to provide feedback on the guideline, leading to some practical adjustments of the proposed guideline.

Detailed survey results can be found in the supplementary material (results, cf. supplementary material 4 - See QR).

## Discussion

The study aimed to evaluate the preparedness of anesthesiologists and residents in managing a fulminant fire in the OR (defined as a Type 2 UC OR fire), where the patient under anesthesia is left behind out of necessity.

Based on the literature review and expert consensus, an appropriate response includes 1) ensuring the safety of the team, 2) maximizing the patient's chances of survival, 3) and minimizing the chance of awareness.

The level of preparedness is based on an analysis of a survey sent to all anesthesiology residents and staff members from the four Flemish university hospitals anesthesia services.

Of the 297 contacted anesthesiologists, 64 responded to the survey, resulting in a response rate of 21.5%.

Despite a reasonable response rate within the selective sample, the limited data prevents drawing statistically significant conclusions that

can be extrapolated to the target population, namely Belgian anesthesiologists, and residents.

However, results indicate an inadequate level of preparedness to manage fulminant OR fires. Whilst most colleagues are aware they work in a high-risk environment, only 36% of the anesthesiologist can give three examples of risk factors, despite the omnipresent plethora in the OR. Worse, only 17.2% of anesthesiologists can articulate the three most essential steps, as found by literature and expert opinion, during a fulminant OR fire where they need to evacuate without the patient. The three essential elements, that compose the most opportune initial reaction are: reducing the FiO2, deepening anesthesia, and covering the patient & ventilator with fire blankets.

Unsurprisingly respondents reported low levels of self-confidence and knowledge regarding the management of these situations.

Consensus is that the use of a guideline, improves the management of such crises, despite it is hard to proof this improves patient survival.

The self-reported knowledge and self-confidence regarding the management of OR fire incidents improved after reading the guideline. The guideline was perceived relevant by 92.2% of respondents and 89% would consider using the proposed guideline in their own institution.

Striking is the difference in experience with simulation training regarding OR fire incidents amongst the respondents who had their specialist training in one of the Flemish institutions (0-13.3%) versus the respondents who had their specialist training outside the Flemish centers (66.7%). Note that only three respondents had specialist training outside the Flemish centers.

Despite the scope of this research being the OR, there are many parallels between the OR and other critical care units such as the intensive care unit (ICU).

The researchers believe that research concerning OR fires and emergency evacuation, will generate transferable knowledge to other critical care areas (ER, ICU).

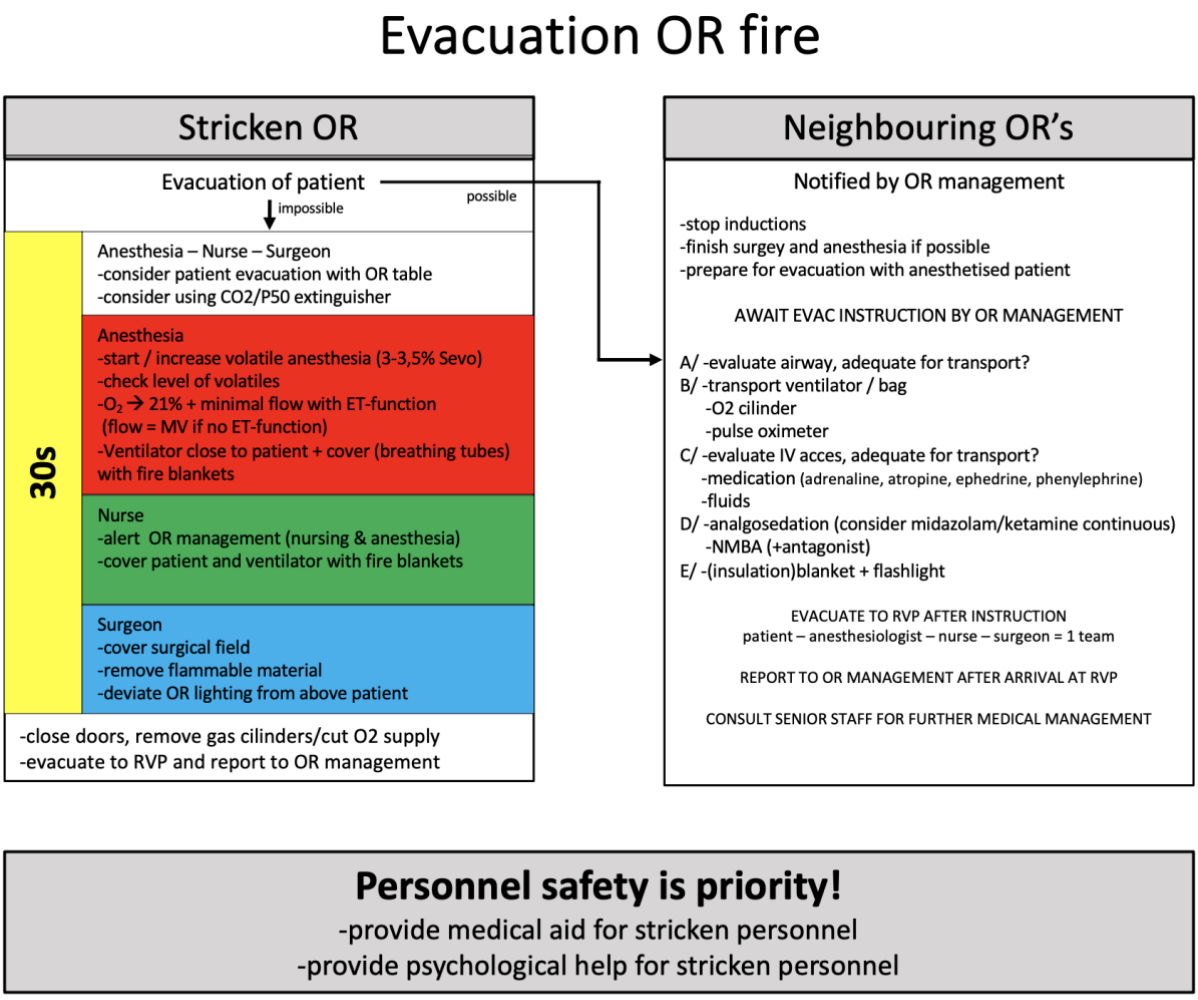


*Fig. 1* — Supplementary material 5: Guideline.

The authors hope this research increases awareness regarding the OR fire risk, leading to increased fire drills and the use of action plans such as the proposed guideline.

As critical care providers, the aim should be to be prepared for any kind of situation whilst providing the best level of care for the patient. Outpacing legislation and direction by JCI, we can increase OR fire safety by implementing small alterations in our current daily practice. These measures can be including fire risk assessment in the safe surgery checklist, provision of an adequate amount of fire blankets in an OR (not just the legal requirement), guideline presence in the OR, etc.

The research objective was to develop a guideline to assist anesthesiologists in managing this situation. This guideline should enable safe actions during a fulminant fire, maximizing the patient's chances of survival and minimizing the chance of awareness. This guideline was developed based on elements from the literature and variant Delphi method and tested for operator feasibility by incorporating it in the survey and gathering feedback. Leading to the current guideline, cf. infra, which can be seen as an evidence based and end user verified guideline optimizing the management of Type 2 UC OR fires with key goals of team safety, patient survival chances and awareness risk mitigation (more detailed version of the guideline, cf. supplementary material 5 - Fig. 1).

### *Limitations*

- The investigated database for relevant literature is solely a medical database. There may be relevant scientific material in databases that are not medical in nature. This stresses the importance of interdisciplinary collaboration in the work up process of guideline production.
- A variant Delphi method was used for the proposed guideline, using a single expert per discipline. The consulted experts were not blinded from the researchers, as the latter interviewed them. More evidential strength would have been obtained blinding the experts from the researchers and seeking multiple experts per discipline.
- An increased number of respondents to the survey might yield statistically significant conclusions.
- There might be a selection bias within the selective sample, as it relied entirely on the voluntary participation of the survey. There may be an overrepresentation of individuals interested in this topic. This can influence the results, as pre-existing interest can also increase prior knowledge compared to uninterested colleagues.

This research should be regarded a pilot study, trying to chart the level of preparedness, and proposing an evidence-based guideline while creating a starting point for further and more thorough research in which the limitations of this study can be addressed.

## Conclusion

This study suggests that Flemish anesthesiologists (including residents) are inadequately prepared for managing fulminant fires in the OR (defined in this article as type 2 UC OR fire), fueled by a lack of knowledge regarding omnipresent risk factors in the OR which limits the possibility of risk stratification and management.

Given the significant impact of OR fires on patient and care givers' safety, increased attention, and measures to address this knowledge gap are warranted.

The study underscores the importance of interdisciplinary collaboration in guideline production and emphasizes the need for further research to address the identified limitations. By increasing awareness and implementing preventive measures, such as integrating fire risk assessment into safe surgery checklists, the safety of OR environments can be enhanced. This study serves as starting point for further research aimed at improving preparedness and patient outcomes in the face of OR fires.

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Both authors confirm to have read and approved the paper, meet the ICMJE criteria for authorship and believe the paper represents honest work and are able to verify and testify on the validity of the reported results.

For the preparation of this article, the authors obeyed the STROBE statement for cross-sectional studies (STROBE statement, cf. supplementary material 6).

A glossary can be found in the supplementary material (glossary, cf. supplementary material 7).

*Conflicts of interest:* There are no conflicts of interest, and no funding was involved.

*Authors contributions:* All listed authors have significantly contributed to the research, analysis and writing of this manuscript. Both authors confirm to have read and approved the paper, meet the ICMJE criteria for authorship and believe the paper represents honest work and are able to verify and testify on the validity of the reported results.

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***Supplementary material - scan QR***

https://qrco.de/bfk7FA

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