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Review article

Physical environment of the operating room during cesarean section: A systematic review

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ABSTRACT

Introduction: Environmental factors in the operating room during cesarean sections are likely important for both women/birthing people and their babies but there is currently a lack of rigorous literature about their evaluation. The principal aim of this study was to systematically examine studies published on the physical environment in the obstetrical operating room during c-sections and its impact on mother and neonate outcomes. The secondary objective was to identify the sensors used to investigate the operating room environment during cesarean sections.

Methods: In this literature review, we searched MEDLINE a database using the following keywords: Cesarean section AND (operating room environment OR Noise OR Music OR Video recording OR Light level OR Gentle OR Temperature OR Motion Data). Eligible studies had to be published in English or French within the past 10 years and had to investigate the operating room environment during cesarean sections in women. For each study we reported which aspects of the physical environment were investigated in the OR (i.e., noise, music, movement, light or temperature) and the involved sensors.

Results: Of a total of 105 studies screened, we selected 8 articles from title and abstract in PubMed. This small number shows that the field is poorly investigated. The most evaluated environment factors to date are operating room noise and temperature, and the presence of music. Few studies used advanced sensors in the operating room to evaluate environmental factors in a more nuanced and complete way. Two studies concern the sound level, four concern music, one concerns temperature and one analyzed the number of entrances/exits into the OR. No study analyzed light level or more fine-grained movement data.

Conclusions: Main findings include increase of noise and motion at specific time-points, for example during delivery or anaesthesia; the positive impact of music on parents and staff alike; and that a warmer theatre is better for babies but more uncomfortable for surgeons.

Introduction

Cesarean sections are one of the most common surgeries, accounting for nearly 30 million procedures per year and around 20 % of births globally [1]. Despite its frequency, a significant number of women/birthing people remain dissatisfied with their birth experience [2]. Poor experience can lead to post-traumatic stress disorder and post-partum depression [3]. As post hoc debriefing is likely insufficient, alone, after a traumatic birth [4,5], a good opportunity to prevent dissatisfaction and trauma could be to ensure a calm and secure environment during what can be a traumatic acute event. Recent World Health Organization (WHO) guidelines highlight the importance of positive childbirth experience, as it enhances mother-infant bonding [6,7].

In a previous systematic review, the primary factors associated with dissatisfaction around birth mostly concerned the amount of caregiver support, quality of the caregiver-patient relationship, and their involvement in decision making. These factors override the influence of

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age, socioeconomic status, ethnicity, childbirth preparation, pain, immobility, or medical interventions [8]. Previous studies have also shown that the level of urgency in the c-section was a crucial factor in birthing experience [3].

On the pediatric side, the caregiving principles of NIDCAP (Newborn Individualized Developmental Care and Assessment Program) have been introduced since the 1970s to reduce stress and promote physiologic stability through adapting the environment (e.g., lower ambient light and sound, increased parental involvement) [9]. To date, these principles are not commonly applied in the cesarean section operating room.

Technical performance might have reached a plateau in terms of its impact given low maternal and fetal morbidity, particularly during planned c-sections, but there is still room for improvement in terms of non-technical skills and the operating room environment. This may now be the key to improving the quality of the mother's experience, limit post-traumatic stress disorders, post-natal depressions, and improve children's health.

The principal aim of this literature review was to systematically examine studies published on the physical environment in the obstetrical operating room during c-sections and its impact on mother and neonate outcomes. The secondary objective was to identify the sensors used to investigate the operating room environment during cesarean sections.

Material and methods

This review was planned, conducted, and reported in adherence with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standard of quality [10].

The initial corpus of scientific publications was constructed using PubMed with the following keywords:

Cesarean section AND (operating room environment OR noise OR music OR video recording OR light level OR gentle OR temperature OR motion data). The initial corpus was constructed on 1 December 2022.

Eligible studies had to be published in English within the past 10 years. We selected clinical trials, randomized clinical trials, *meta*-analysis, reviews, and systematic reviews. We used the human filter on Pubmed as well. Studies had to investigate the physical operating room environment during cesarean sections. Other obstetrical or surgical interventions were not included, as well as preoperative or postoperative interventions. Simulation studies were not included neither. References list of obtained articles were also screened.

Two reviewers (MLL and CB) independently performed the initial screening of the studies based on their titles and abstracts. The texts of all relevant studies were then reviewed. For each study, we reported which aspects of the physical environment were investigated in the OR (noise, music, movement, light or temperature) and what sensors were used to do so. We also reported whether or not surgeons' and/or parents'

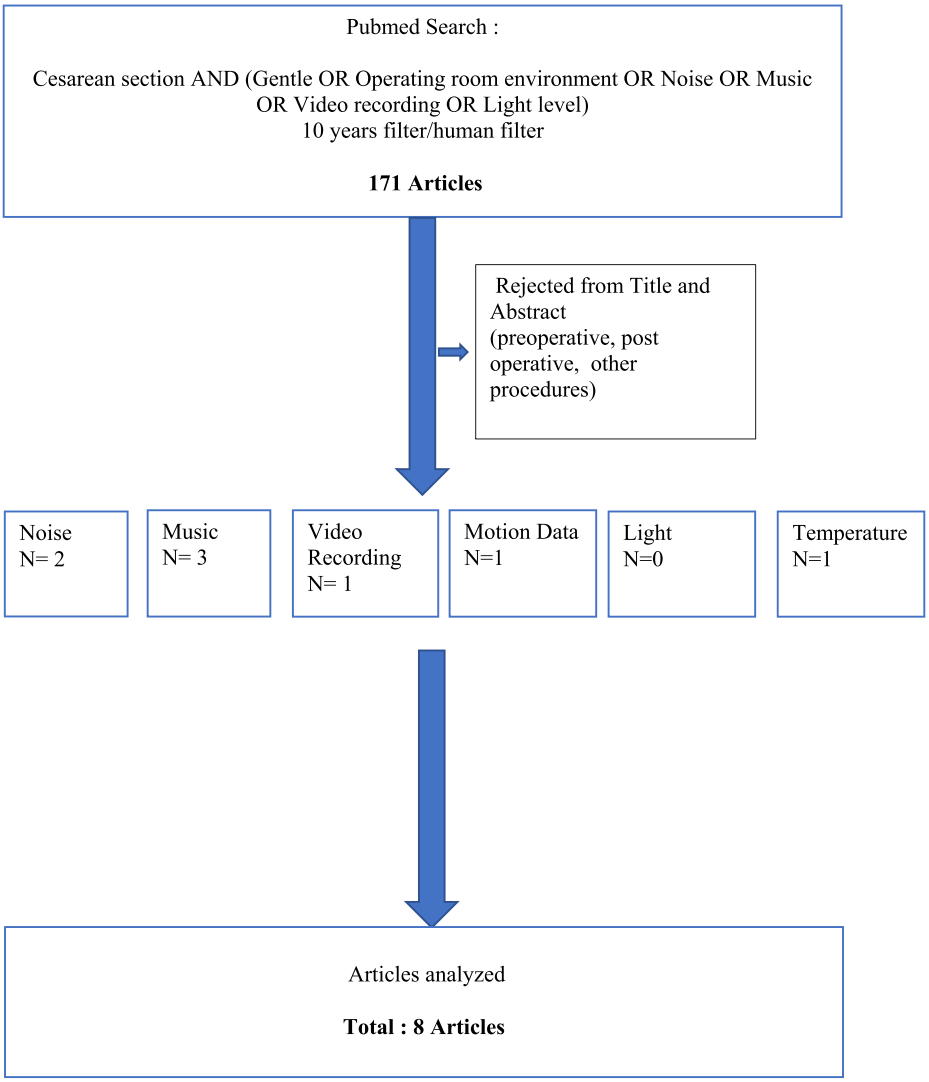


Fig. 1. Flow chart.

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experience was investigated as well as neonatal outcomes.

Results

A total of 105 studies were screened, from which 8 articles were selected based on the title and the abstract in PubMed (Fig. 1 – Article flow chart). Study characteristics (i.e., authors, year of publication, type of study, sample size, sensors used, primary study outcome and main result) are shown in Table 1.

Noise in the OR

One study analyzed the noise level in the operating room during the specific intervention of cesarean delivery using a sound meter and a sampling time set at every 60 s. They compared the noise level between elective/urgent/emergency cesarean sections. Noise levels were measured in specific time points: when entering the OR, during neuraxial anesthesia, five minutes before incision, three minutes before incision, one minute before incision, during skin incision and at baby delivery. They included 400 non-emergency cesarean sections and 40 emergency cesarean sections. Although average noise levels across all time points in the non-emergency group and emergency group were not significantly different (66 dB and 70 dB respectively), they found significant differences at particular time points: while entering the room, during neuraxial anesthesia, 1 min before incision, during skin incision and at baby birth.

However, some biases were raised. The authors mentioned a possible Hawthorne effect, as while sound was intended to be recorded without the knowledge of individuals in the OR, personnel might have noticed the sound meters and modified their noise levels. Moreover, most of their emergency cesarean sections were under general anesthesia and they appeared to be noisier than those under neuraxial anesthesia. Also, their ratio elective/emergency c-section was 10:1, indicating a high number of elective cesarean section on patient's demand. Finally, the impact on parental satisfaction, stress, or neonatal outcomes was not assessed.

Another study by Jenkins et al. measured sound levels during cesarean section, also using a sound meter [11]. They included 30 cesarean sections and measured the noise during three phases: the establishment of regional anesthesia; the testing of said block; and after delivery of the fetal head. Mean noise levels were 62.53.9 dB during establishment of the block, 63.94.1 dB during testing, and 66.85.0 dB after delivery, and the results were significantly different ($p < 0.001$). Sudden and loud (>70 dB) noises in the theatre, as well as non-clinical conversations, all increased during each of the three phases. Again, the impact on maternal or neonatal outcomes was not investigated.

Music in the OR

One recent *meta*-analysis analyzed the effect of music on anxiety in women undergoing cesarean delivery [12]. It included two randomized control trials [13,14] with a total of 432 women and measured intraoperative anxiety. Both studies showed that music during surgery lowered the level of anxiety for the mother, regardless of the anxiety measurement tool used. The patient groups exposed to music during the intervention had lower intraoperative anxiety levels than the controls

Table 1
The different aspects of cesarean section environment investigated in each study included.

Author and date	Journal	Type OR/LR	N	Noise	Light	Motion data	T°	Music	Sensors used	Results
Sheridan et al. 2021	Int J Obstet Anesth	PS	440c/s	Noise at 8 time points	No	No	No	No	Sound level meter (General)	Urgent c/s is noisier at 8 time points
Jenkins et al. 2015	Anaesthesia	PS	30c/s	Noise in 3 points (mean sound level)	No	Numbers of Enter and exit the room	No	No	Sound-level meter	c/s noisier at the beginning time points Busier at the beginning of c/s
Drzymalski et al. 2021	J Matern Fetal Neonatal Med	RCT	150	No	No	No	No	Mozart versus patient music versus no music	None	Decreased anxiety with Mozart music
Magee et al. 2014	Am Board Fam Med	Qualitative	5 years	Minimal conversation between staff	No	No	Yes (use bear hugger)	Yes (music parents's choice)	None	Satisfaction of women and team
Weingart et al. 2021	AM J Obstet Gynecol MFM	Meta analysis, 3RCTs	432c/s		No	No		Yes Music vs no music (large range of music)	None	Music decreases intra operative anxiety
Hepp et al. 2018	BMC pregnancy childbirth	RCT	304	No	No	No	No	Yes	Systolic blood pressure, Salivar cortisol	Music reduces stress during c -section
Li et al. 2012	Int J Gynaecol obst	RCT	60	No	No	No	No	Yes	Holter mother assessment	
Stevens et al. 2018	Women Brith	Ethnography study Focus groups, interviews	21c/s	Video recording	No	No	No	No	Video recording	Skin to skin benefits
Dureya et al. 2016	American J Obstet Gynecol	RCT in Clusters	791c/s	No	No	No	Yes	No	Infrared thermometer.	Decrease in neonatal hypothermia when room is 23 °C

c/s: cesarean section.
RCT: randomized controlled trial.
Ps: Prospective study.

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did. A large variety of musical styles were studied: classical (Mozart), Western music, jazz, religious music, R&B, gospel, soft rock, and Spanish guitar. In the subgroup analyses, the same relationship persisted even when the cesarean delivery was unscheduled and regardless of whether or not the music was selected by the patient or by the study team. Music was also associated with decreased opioid use.

Motion/quantity of movements in the OR

The aforementioned study by Jenkins et al. also aimed at investigating potential distractions in the OR during the anesthesia phase and therefore measured the number of entrances to and exits from the operating room during the intervention. The number of entrances/exits were the highest during the establishment of the block, 0.6[0.3;0.8] per minute, and decreased over the subsequent periods: establishment of blockade 0.5[0.4;0.7] per minute and after fetal head delivery 0.2 [0;0.4] ($p < 0.001$). They did not measure the quantity of other movements inside the operating theatre aside from entrances and exits, although it still revealed how busy an operating room can be.

Temperature in the OR

One randomized controlled-study was found regarding the temperature in the operating room during cesarean section delivery and its impact on neonatal hypothermia prevalence on arrival at nursery [15]. The authors enrolled 791 women undergoing a cesarean section and allocated to either an operating room temperature of 20 °C, which was the standard group, or 23 °C which was the study group. They showed that this modest increase in the room temperature decreased the rate of neonatal hypothermia from 50 % to 35 % ($p < 0.001$). It also decreased maternal hypothermia rates without increasing fever rate. Although 56 % of the surgeons reported discomfort during the 23 °C period, only 21 % of them reported that it affected their surgical performance. However, they all (100 %?) mentioned that this temperature would be acceptable if it was necessary for the patients.

Light in the OR

We found no literature about light levels during cesarean sections.

Discussion

Main findings

Few studies assessed the potential of changing the physical environment of the operating room to optimize the mother's comfort and infant outcomes. Main findings include increase of noise and motion at specific time-points, for example during delivery or anaesthesia; the positive impact of music on parents and staff alike; and that a warmer theatre is better for babies but more uncomfortable for surgeons.

Strengths and limitations

This review emphasizes the lack of data about environmental factors during cesarean sections. Indeed, no randomized controlled study was found and most of the studies included are only observational studies. However, to date it is the first review that the summarize this data.

Interpretation

Even if cesarean delivery practices have changed substantially over the past 30 years, with the introduction of the skin-to-skin technique and encouraging the presence of the co-parent, there is still room for improvement16, [17], especially as cesarean sections take place in a noisy, busy, and cold room contrary to most spontaneous vaginal births. The environment in the operating theatre has an influence on the patient's anxiety levels [27]. Terms such as "gentle cesarean" or "natural cesarean" have been applied to a more patient-centered approach to operative delivery [17]. It comprises different techniques with a central feature being placing the newborn skin-to-skin on the mother's chest, avoiding separation, and promote breastfeeding. It also usually includes the following environmental elements: minimizing extraneous conversation among caregivers in the operating room and adding music of the parents' choice playing, if desired. However, this is a common option only for scheduled/elective cesarean sections and in smaller institutions (<500 births per year) [17]. Diminished ambient light, low noise environments and restrained movement in the room, although instinctively desired by the teams, were never rigorously studied in the literature. Each of these physical elements may help to redesign cesarean delivery practices and may positively affect maternal–infant bonding [16].

Cesarean sections require numerous healthcare practitioner such as an obstetrician, a resident, a midwife, anesthesia doctor and nurse, and scrub nurses. Even when it is not a red code, that is an extremely urgent cesarean section requiring fetal extraction within 15 min, each step of a caesarean section is important and present opportunities for adverse critical events. These events include: difficulty obtaining sufficient maternal analgesia and various anesthesia issues including administration of uterotonics; surgical problems such as difficulty accessing the uterus or extracting the fetus or placenta; hemorrhage and complications in terms of managing maternal hemodynamics; and pediatric concerns such as neonatal resuscitation. It is not hyperbolic to say that these urgent interventions are at the same time the most important and the most dangerous time of the mother's life who often has little to no warning and can be understandably distressed and frightened [18]. Although most labor and birth care providers have positive attitudes about gentle cesarean birth [19], the feelings of the patients are often forgotten in the surgical environment in these cases. [20].

Noise

In this review noise varied during caesarean, with specific time points associated with increased noise. Excessive noise may have negative implications for both clinicians and patients [21–23]. High noise levels impaired the performance of obstetric teams managing postpartum hemorrhage during vaginal birth [24]. Preventive interventions may be beneficial. In other specialties beyond obstetrics, a pediatric surgery department tried to implement a noise reduction program. They managed to reduce the overall operating theatre sound levels from 63 dB(A) to 60 dB(A) [25]. With this decrease they observed a significant decrease in complication rates. Also, this intervention also decreased both the surgeon's pre- and post-operative rise in cortisol by approximately 20 %. In another study, medical students exposed to noise showed higher stress level and higher heart rate when completing a laparoscopic task [26].

Cesarean sections require rapid coordination and communication. A mean noise level of 55–77 dB in ORs have been reported across multiple surgical specialties, but emergency cesarean sections appeared to be the noisiest of them, with transient noise levels reaching 100 db. Noise appeared to be higher during emergency than during non-emergency cesarean deliveries [21]. Even if some noises are part of the process and indicate positive outcomes, like the noise of a baby crying, other noises may not be necessary for the proper conduct of cesarean section. Possibly maternity teams could and should work on reducing noise pollution, such as by turning off the aspiration when it is not useful and by avoiding yelling for the check list or displaying the instruments.

Motion data in other surgical procedures

The study by Jenkins et al. is the only one that addressed how busy an operating room is during a cesarean section. Assuming a one-hour operating theatre occupation time for a cesarean section, a total of 24

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persons might have entered or left the room, with approximately one person entering or exiting every two minutes during the first and busiest phase of cesarean section, which is a lot for the mother and the newborn. Other data confirmed that extraneous movement occurring in the obstetric operating theatre environment creates a source distraction for the surgeon and also may affect the patient concentration as well. However, to our knowledge, more nuanced quantitative motion data measured by sensors inside the operating room has yet to be studied, yet is needed. In a study of movement in simulated obstetric emergencies in labour ward rooms, complex movement patterns emerged which were dependent on profession (doctor versus midwife) and experience (senior versus junior). Leadership in emergencies was multimodally achieved; senior professionals drew on discursive strategies, material space, and body and gaze orientation, to enact being a 'leader', whereas movement for junior staff was more pronounced and not always for a specific purpose [33].

Light

We found no studies concerning light in caesarean theatres. For natural vaginal birth, it is common practice to have soft ambient light in the room. Some studies show that excessive light may be an inhibiter for the birthing process, via the reducing the action of melatonin, a hormone implicated in early sleep, on uterine contractility [28]. Artificial light alters birthweight, gestational length and affects obstetric outcomes in terms of labor duration and neonatal short-term health [28]. During cesarean sections, light pollution may also affect neonatal outcomes [28], as melatonin levels in the umbilical cord are influenced by the mode of delivery [29,30]. However, this is difficult to optimize as operators need sufficient light to operate, and all theatre staff have to be first safe and efficient. Adaptive management of operating theatre lighting could potentially optimize its availability for when and where needed.

Temperature

The question of the temperature is slightly different as the interests for the neonate and for the team appear in current literature divergent [31]. The temperature of the operating theatre is an influential factor to the women's and neonates' body temperature. The optimal delivery room temperature is 25–28 °C by the World Health Organization for the case of vaginal delivery in order to minimize neonate hypothermia [32]. Unfortunately, this temperature range is not well tolerated by operating room staff [31]. In Duryea et al.'s randomized control study, ambient temperature in the operating room of xx surgery of 23 °C seemed to be the right balance between hypothermia rates and surgeon comfort [15]. Existing literature for caesareans shows so far that 23°might be accepted by surgeons, but at the expense of increased discomfort. Similarly to light, more sophisticated approaches such as separate micro-environments may be necessary.

Progressing to adaptive environments

NIDCAP (Newborn Individualized Developmental Care and Assessment Program) is an individualized environment adaptation program made for neonates. In this program, the environment is modulated is response to observations of the baby. Care, entrances to the room, noise, voices, are always adapted to the baby's comfort and well-being. NIDCAP infants have shown improved brain function with improved reflexes like sucking, cuddling, crawling, and decreased motor stress signals compared with controls [34]. At 9 months, they demonstrate better mental development, emotion regulation, and motor quality. The operating theatre environment could also be adapted to the neonate, with a continuum between the atmospheres of both environments.

Conclusion

This literature review shows that there is room for research about environmental factors during cesarean sections, specifically the creation of a calming and reassuring ambiance for parents undergoing surgical birth. Further research should concentrate on the impact of noise, light, and motion data in the obstetrical operating room, investigate its impact on maternal and pediatric outcomes, and evaluate interventions, particularly those which balance clinical patient outcome with experience for parents and also surgeons and theatre staff.

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CRediT authorship contribution statement

MLL: Conceptualization, investigation and writing original draft. CB: Investigation. JB: writing review and editing. AH: conceptualization. FV: Supervision, resources, software. DSi: Conceptualization, Writing review and editing. DSt: Conceptualization and Project administration. PJ: Conceptualization, Methodology, Supervision and Writing review.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejogrb.2023.06.029.

Role of authors : MLL: Conceptualization, investigation and writing original draft. CB: Investigation. JB : writing review and editing. AH: conceptualization. FV: Supervision, resources, software. DSi : Conceptualization, Writing review and editing. DSt: Conceptualization and Project administration. PJ: Conceptualization, Methodology, Supervision and Writing review.

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