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The Perception and Attitude Toward Noise and Music in the Operating Room: A Systematic Review

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ABSTRACT

Background: Environmental noise pollution is regarded as a general stressor. Noise levels frequently exceed recommended noise levels by the World Health Organization in hospitals, especially in the operation room. The aim of this systematic review was to assess the effects of noise pollution on patient outcome and performance by operation room staff. In addition, the perception and attitude toward playing music in the operation room, which can increase noise levels, were assessed as well.

Materials and methods: A systematic literature search of the databases Embase, Medline Ovid, and Cochrane from date of database inception until October 16th, 2020 using the exhaustive literature search method was performed. Prospective studies evaluating the effect of noise on the patient, surgeons, anesthesiologists, nurses, and other operation room staff, or perception and attitude toward playing music in the operation room, were included. This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines and was registered with PROSPERO (ID: 208282).

Results: The literature search generated 4758 articles, and 22 prospective studies (3507 participants) were included. Three of the four studies that investigated the effect of noise on patient outcome reported a significant reduction of complication rate in surgical patients, when noise levels were lower. Six studies assessed the effect of noise in the operation room on the staff (1383 participants). Over half of the surveyed staff found noise levels to be a disturbing stressor and negatively impact performance. Although music increased decibel levels in the operation room, most surveyed staff was positively predisposed toward playing music during surgery, believing it to improve both individual and team performance. In general, music was not considered to be distracting or impairing communication.

Conclusions: Higher noise levels seem to have a negative effect on patient outcome and adversely affect performance by members in the operation room. Further research is needed to assess whether this knowledge can benefit patient outcome and surgical performance. Notably, attitude of surgical team members toward music during surgery is generally regarded favorable.

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Introduction

Noise is defined as an unpleasant and unwanted sound. Environmental noise pollution is regarded as a general stressor, increasing mental stress, the development of cerebral cardiovascular disease, and the risk of hearing loss.[1,2] During the past decades, noise pollution has increased exponentially in hospitals.[3,4] High noise levels are nowadays prevalent in the operation room (OR) and frequently exceed both the recommended threshold of 30 dBA set by the World Health Organization,[5] as well as the American Occupational Safety and Health Administration standard.[6] Peak levels have been noted to vary between 80 and 119 dBA.[4,5,7] During neurosurgery and orthopedic surgery, noise levels exceed 95 dBA for most surgery duration,[7] which equals standing next to a lawn mower. Noise pollution was observed to be mainly caused by staff-related behavior and surgical equipment, increasing as the day progressed.[5,8-10] Playing music in the OR deserves a specific mention. It increases decibel levels, and some have questioned its safety in regard to communication and distraction.[11]

Previous studies mainly focused on solely measuring decibel levels in the OR, and several recent reviews explored this topic.[4] Therefore, the aim of this systematic review was to assess the effect of noise pollution on patient outcome, as well as staff perception and performance in the OR. Besides potential negative health effects on members of the surgical team, high noise levels can also increase stress, impair communication, reduce concentration, and affect performance.[2] Although beneficial effects of music regarding patient outcome, patient satisfaction, and surgical performance have extensively been investigated,[12-15] the subjective perception by OR staff regarding music in the OR has not. Therefore, the attitude of OR staff, including surgeons, anesthesiologists, and nurses will be evaluated as well, taking aforementioned domains into account.

Material and methods

This systematic review was prospectively recorded with the PROSPERO database (ID: 208282). The Preferred Reporting Items for Systematic Reviews and Meta-analysis guidelines were followed.[16]

Literature search and study selection

A systematic literature search was performed with assistance of a biomedical information specialist. The exhaustive literature search method was used to search the databases Embase, Medline Ovid, and Cochrane from date of database inception until October 16th, 2020.[17] Full search syntax is available in Appendix A. Three reviewers (V.F., P.O., and N.M.) independently assessed which of the retrieved articles were eligible for inclusion in accordance with prospectively recorded inclusion criteria. Published, prospective studies in the English language evaluating the effect of noise in the OR on patient outcome, defined as postoperative complication rate and length of stay, as well as performance by members of the OR team, were eligible for inclusion. Furthermore, the perception and attitude toward noise in the OR by members of the OR regarding the domains performance, team performance and team work, stress, communication, and distraction were assessed as well. Finally, given that music increases decibel levels and can be considered to be a type of noise, studies evaluating the perception of and attitude by members of the OR team toward music in the OR were included as well. Studies solely evaluating decibel levels in the OR were not included. Manual cross-referencing of included studies was performed additionally.

Risk of bias assessment, data extraction, and data analysis

Risk of bias was independently assessed by the three reviewers (V.F., P.O., and N.M.). Different risk of bias assessment methods were used depending on the study type. For prospective randomized controlled and crossover trials, the Cochrane Collaboration's tool for assessing risk of bias in randomized trials was used.[18] Risk of bias in observational studies without interventions was assessed using the Newcastle–Ottawa Scale.[19] For risk of bias assessment of surveys, the risk of bias instrument for cross-sectional surveys of attitudes and practices by the CLARITY Group was used.[20]

Study data extraction was independently performed using a custom-made data extraction sheet and mutually discussed among the three reviewers (V.F., P.O., and N.M.). Data regarding the outcome measures of interest as stated previously which were presented as means and standard deviations, medians and interquartile ranges, and percentages in the included studies were extracted. If case study data were only presented through plots or images, the online available data extraction software WebPlotDigitizer (Version 4.1) was used to plot the figures and estimate the data, with at least two reviewers independently performing this task.[21] Attitude and perception toward music in the OR concerning the domains performance, team performance and team work, stress, communication, and distraction were presented using a 5-point Likert scale, which was the most frequently used survey method. The low end[1,2] of the scale represented a negative or disagreeing answer, the middle scale,[3] a neutral answer, and the high end,[4,5] a positive or agreeing answer in regard to the survey question. In some cases, an additional 'don't know' option was presented. Because of the different ways questions were asked, as well as the difference in proportion of surveyed surgical, anesthesiological, and nursing staff in each study (i.e., one study assessed the opinion of anesthesiologists only, whereas another received twice as many responses from nurses compared with surgeons), we did not calculate an overall mean or perform additional statistical analysis. No meta-analysis could be performed because of the limited number of studies, clinical heterogeneity, and varying methods of data presentation.

Results

The literature search generated 4758 articles, with 3631 remaining after deduplication. Ninety-three articles were

assessed full text by the three reviewers, with 71 being excluded in accordance with the predefined exclusion criteria after full-text assessment as they were not written in the English language ($n = 3$), were not conducted in the surgical setting ($n = 2$), were not prospective studies ($n = 10$), did not contain relevant outcome measures ($n = 23$), only measured decibel levels ($n = 29$), or other reasons ($n = 4$). As a result, 22 prospective studies (3508 participants) were included in this review, with four assessing the effect of noise in the OR on the patient, six the effect of, perception toward, and attitude toward noise by members of the OR team, and 13 the perception of and attitude of the OR team toward music in the OR (Figure) (Table 1). One study assessed the effect of noise both on the patient and the surgical team.[8] There were no disagreements concerning study inclusion or data extraction among the three reviewers.

The effect of noise in the OR on the patient

The effect of noise on patient outcome was assessed in four studies (350 patients).[8,22-24] Three studies reported a significant reduction in postoperative complication rate, when noise levels were lower. Two prospective observational studies observed significantly higher noise levels during surgery in patients who developed surgical-site infection after elective hernia repairs and open abdominal surgery.[22,23] Surgical-site infection occurred in five out of 64 (7.8%) patients with hernia, with a mean increase in noise of 11.3 dB when comparing the infection and no infection group.[22] After open abdominal surgery, surgical-site infection occurred in six out of 35 (17%) patients, whereas median sound levels were 43.5 dB (26.0-60.0) on average in these six patients *versus* 25.0 (25.0-60.0) in the patients who did not have a surgical-site infection.[23] In the third study,[8] a noise reduction program was implemented in the pediatric surgery department, which consisted of sound-reduction devices and behavioral rules limiting conversation, opening of the OR door, and monitor alarms. This noise reduction program significantly reduced both decibel levels during 114 pediatric surgical procedures by approximately 50% (3dBA, equivalent to a twofold increase in perceived sound level), as well as peak noise levels by over 50%. Postoperative complication rate was also significantly lower in the noise-reduction group (17.9% *versus* 34.5%, $P < 0.05$). The fourth study included that investigated the effect of noise reduction on patient outcome which employed the use of a wireless audio system during 69 robot-assisted surgical procedures, which reduced peak noise level events above 70 dB, but not average noise levels during surgery. No statistically significant differences were observed regarding postoperative complication rate or length of hospital stay when comparing these with 68 control cases.[24]

The effect of noise in the OR on members of the OR team

Six studies assessed the effect of, perception toward, and attitude regarding noise in the OR of the health care staff (1383 participants).[8,10,25-28]

Two studies evaluated the stress-inducing effects of noise in the OR. Noise levels in the OR were regarded as a disturbing stressor by over half of the surgeons, anesthetists, and OR

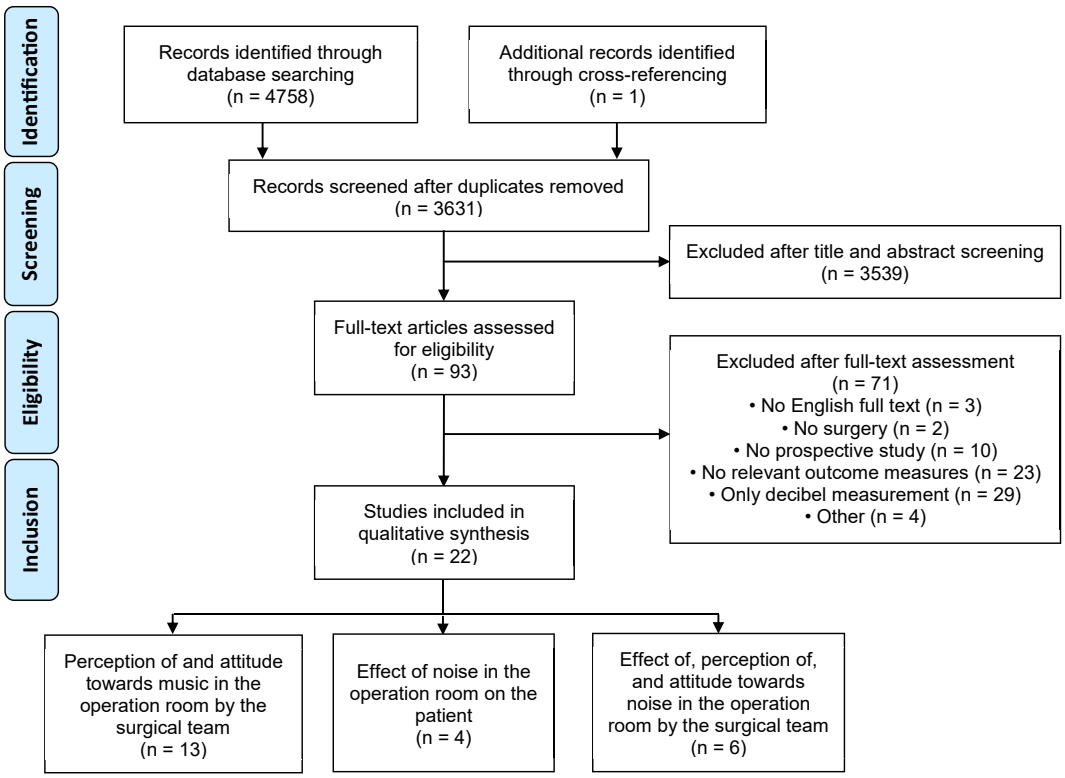

Fig – PRISMA flow chart. n = number of studies. One study (Engelmann *et al.*, 2014) assessed the effect of noise both on the patient and surgical team. (Color version of the figure is available online.)

Table 1 – Study characteristics.

Study	Study type	Surgical procedure	Setting	N	Study population	Outcome assessed
Cheriyan 2016	Repeated measure design	Simulated setting, five trials with 20 words	Simulated setting with ambient, ambient and equipment, ambient and equipment, and music sound setting	4 (1 OR team)	Operation room team members	Auditory processing under three different noise conditions (percentage correct response rate)
Dholakia 2015	Observational study	Elective hernia repair	Operation room	64	Adult patients	Relation between noise levels and 30-day surgical-site infection rate
Engelmann 2014	Nonrandomized, two-armed clinical trial	Pediatric surgery	Nonoperation-related noise reduction program in the operation room	114	Pediatric patients	Postoperative complication rate
				16	Pediatric surgeons	Stress response (salivary cortisol, electrodermal activity) Distraction and communication
Enser 2010	Randomized crossover trial	Simulated setting	Noisy *versus* quiet environment	42	Anesthesiology residents	Performance (clinical reasoning through script concordance test)
Faraj 2014	Cross-sectional survey study	*Not applicable*	Single-center, general hospital survey (United Kingdom)	52 (102)	Surgeons, nurses, anesthesiologists, other OR assisting staff	Perception and attitude on music in the OR (prevalence, effect on enjoyment, efficiency, (team) performance, and distraction)
George 2011	Cross-sectional survey study	*Not applicable*	Single-center hospital survey (India)	100	Surgeons, nurses, anesthesiologists	Perception and attitude on music in the OR (prevalence, enjoyment, stress, performance, communication)
Hawksworth 1997	Cross-sectional survey study	*Not applicable*	Nationwide survey (United Kingdom)	144 (200)	Anesthesiologists	Perception and attitude on music in the OR (prevalence, enjoyment, performance, communication, distraction)
Keller 2018	Prospective observational study	Elective open abdominal surgery	Operation room	110	Surgeons, nurses, anesthesiologists	Self-reported distraction levels of noise in the OR
Kumar 2013	Cross-sectional survey study	*Not applicable*	International survey	68 (110)	Neuroanesthesiologists	Appropriateness of playing music in the OR
Kurmann 2011	Prospective observational study	Elective open abdominal surgery	Operation room	35	Not specified	Relation between noise levels and 30-day surgical-site infection rate
Lee 2013	Cross-sectional survey study	*Not applicable*	International survey	523 (2057)	Urologists	Prevalence of music in the OR
Makama 2010	Cross-sectional survey study	*Not applicable*	Survey (Nigeria)	162 (167)	Surgeons, nurses, anesthesiologists, other OR assisting staff	Perception and attitude on music in the OR (enjoyment, performance, stress, distraction)

Moorthy 2004	Randomized crossover trial	Laparoscopic suturing (Pelvic laparoscopic box trainer)	Simulated setting with quiet, noise at 80-85 dB, and music sound setting	12	Surgeons	Laparoscopic task performance (Task completion time, movements, path length, global score, accuracy, knot quality)
Narayanan and Gray 2018	Cross-sectional survey study	*Not applicable*	Single-center, tertiary teaching hospital survey (New Zealand)	106 (234)	Surgeons, nurses, anesthesiologists, other OR assisting staff	Perception and attitude on music in the OR (prevalence, enjoyment, (team) performance, communication, distraction)
Oliver 1999	Cross-sectional survey study	*Not applicable*	Single-center, tertiary teaching hospital survey (United Kingdom)	35 (45)	Surgeons, nurses, anesthesiologists	Perception and attitude on music in the OR (prevalence, enjoyment, performance, concentration, distraction)
Padmakumar 2017	Cross-sectional survey study	*Not applicable*	Nationwide survey (United Kingdom)	519	Surgeons, nurses, anesthesiologists, other OR assisting staff, medical students	Music adverse influence perception and attitude on noise in the OR ((team) performance, stress, communication, concentration)
Tsafrir 2020	Nonrandomized, two-armed clinical trial	Gynecological and urological robotic surgical procedures	Wireless audio headset	137	148 team members	Postoperative complication rate. Self-report communication, performance, teamwork, and mental workload quality
Tsiou 2008	Cross-sectional survey study	*Not applicable*	National multicenter survey (Greece)	684	Surgeons, nurses, anesthesiologists	Perception and attitude on noise in the OR (prevalence, performance)
Ullman 2008	Cross-sectional survey study	*Not applicable*	National multicenter survey (Israel)	171	Surgeons, nurses, anesthesiologists	Perception and attitude on music in the OR (prevalence, concentration, communication, distraction)
Way 2013	Randomized crossover trial	Peg transfer task (Ethicon Skill Kit)	Simulated setting with quiet, filtered, OR noise, OR noise and music condition	15	Surgeons with varying degree of experience	Auditory processing under four different noise conditions (Speech in Noise Test—Revised)
Weldon 2015	Prospective, nonrandomized observational study	13 laparoscopic and seven open surgical procedures	Two operating theaters	5 (5 OR teams)	Surgeons, scrub nurses	Repeated request number (univariate analysis) after dividing surgical procedures to with and without intraoperative music
Yamasaki 2016	Cross-sectional survey study	*Not applicable*	Single-center survey (United States)	390 (409)	Surgeons, nurses, anesthesiologists	Perception and attitude on music in the OR (prevalence, enjoyment, concentration, communication, distraction)

N = Number of participants. For cross-sectional studies, the number to which the survey was distributed is presented in (brackets), if reported.
Cheriyan 2016: Five trials with 20 words were spoken by the surgeon and recorded by the first assistant, anesthesiologist, and circulating nurse during three different sound level settings.
Weldon 2015: 20 surgical procedure video recordings were assessed.

nurses surveyed.[28] The aforementioned noise reduction program used during pediatric surgery reduced both intraoperative salivary cortisol rise by 20%, as well as electrodermal potential peaks indicative of severe stress by 60% of the performing surgeons. However, these results were not statistically significant ($P > 0.05$).[8]

Four studies evaluated the effect of noise on performance. Noise levels in the OR negatively impacted performance and concentration in accordance with more than half of the surveyed staff.[27,28] Laparoscopic task performance was not affected by a more noisy environment when 12 surgeons with different experience levels were evaluated during simulated laparoscopic suturing environment.[26] A noisier environment did significantly impact clinical reasoning by anesthesiological residents when compared with a quieter environment. Performance on the script concordance test was significantly reduced (59.0 (56.0-62.0) *versus* 62.8 (60.8-64.9), $P = 0.04$), although the difference in performance lessened with experience of the resident.[25]

Two studies evaluated the effect of noise in the OR on communication and distraction. Communication was the factor believed to be most adversely affected by noise in the OR.[27] Self-reported distraction by noise seems to be more present in surgeons (39 and 43% of main and assisting surgeons) when compared with anesthesiologists (16%).[10]

Perception and attitude toward playing music in the OR

Ten studies evaluated the perception by and attitude of the OR staff on playing music in the OR through cross-sectional surveys (1751 participants) (Table 2),[29-38] with an additional three studies assessing its effect on auditory perception and communication (24 participants).[11,39,40] The prevalence of music in the OR was assessed in seven studies (1486 participants), with music being played during a majority of surgical procedures in hospitals around the world.[29-31,33,35,37,38] In general, the majority enjoyed music in the OR with positive approval rates varying between 60% and 90% (eight studies, 1057 participants).[29-32,34-36,38] In six studies (949 participants),[29-31,34,35,38] individual performance or concentration was subjectively either improved or unaffected by music according to most surgeons, anesthetists, and OR nurses surveyed. Music was also deemed to be beneficial for team performance and team work (158 participants).[29,35] Furthermore, music was perceived to reduce stress (398 participants).[30,34-36]

Whether music was considered distracting differed. Music was not deemed to be distracting in general,[34,38] but opinions differed in regard to critical situations when a problem was encountered.[29,31,35-37] Communication was regarded to be either unaffected or positively influenced by music by approximately 60% of respondents (911 participants).[30,31,35,37,38] In contrast, two studies that, respectively, evaluated 15 surgeons and four physicians acting as an OR team reported a significant reduction in the correct rate of auditory speech perception in a simulated setting, when music was added.[39,40] An observational study using OR video recordings observing five surgeons performing 20 surgical procedures reported a significant increase in repeated request rate when music was played.[11]

Risk of bias assessment

Six studies used a crossover design[8,24-26,39,40] (Table 3). Although three used a randomization, only one specified the randomization method (17%),[25] leaving risk of selection bias either unclear or high. Because of the intervention, blinding of participants was not possible. In three studies, outcome assessors were blinded (50%).[8,25,26] All studies used an appropriate crossover design, although carry-over effect addressment was not specified. In two studies, other bias risk category was deemed high as both studies failed to take the Lombard effect into account, the physiological phenomenon that speakers increase their voice level and adapt their speech manner when in the presence of increasing background noise levels.[41]

In four observational studies,[10,11,22,23] insufficient information was provided to adequately assess bias risk in regard to selection and comparability in accordance with the Newcastle–Ottawa Scale and potential confounders were not addressed. Assessment, follow-up, and adequacy of outcome were deemed to be appropriately assessed in all four studies.

Twelve studies used a cross-sectional survey study design (Table 4).[27-38] Bias risk in regard to sample representativeness was either low or probably low risk in 10 studies (83%), as a random selection of OR staff was assessed in a single hospital, multicenter, nationwide, or international. It was deemed unclear in one (8.3%),[34] and probably high risk in one study (8.3%).[36] Adequacy of response varied, with six studies (50%) reporting a response rate of at least 60%. Three studies (25%) had a potential high risk of bias as less than half of potential participants filled out the survey.[29,33,35] In three studies (25%), response rate was not reported. In 10 studies, risk of bias due to missing data in the completed questionnaires was considered low, whereas two studies (17%) did not specify the amount of missing data.[28,29] Although the universally known Likert scale was used in most questionnaires, only two studies (17%) used a previously validated questionnaire.[29,32] One survey study reported conflicting results when comparing the numbers presented in the results paragraph with the figures, concerning the response rate and percentage of distraction.[29] In three studies,[31-33] only a specific group of specialists were surveyed regarding the topic of playing music in the OR.

Discussion

Noise has been universally reported to act as a stressor, increasing autonomic nervous system activity and stress hormone levels.[2,42-44] Even relatively short-lasting, acute noise exposure has been associated with increased cardiovascular stress.[45] Attention to the attenuation of the stress response using Enhanced Recovery after Surgery and similar fast track protocols has significantly improved postoperative patient outcome.[46] A more vigorous response has been associated with a higher postoperative complication rate,[14,47] with the stress hormone cortisol playing a role in wound healing and infection occurrence.[48,49] Only a very limited number of studies to date evaluated the effect of OR noise on surgical patients, as presented in this systematic review. Most

Table 2 – Attitude and perception toward music in the operation room.

Domain	Study	*n*	SUR	ANA	NUR	Survey question	Assessment method	Result (%)				
								Disagree		← →	Agree	
Individual performance	Faraj 2014	52	27	6	8	"I feel I perform better when music is played in the operating theater"	Likert scale 1-5 (with 6th option do not know)	7 Do not know: 2	12	32	17	30
	Makama 2010	162	94	18	22	Does familiar music enhance performance?	List of options	NR		NR	86.4	
	Narayanan and Gray 2018	101	37	29	35	How does music affect the surgeon's performance?	Likert scale 1-5 (Negative-positive)	0	6	59	34	2
Concentration	George 2011	100	44	25	31	"Do you think music improves concentration?"	Likert scale 1-5	11	16	10	50	13
		100	44	25	31	"Do you think music reduces your vigilance?"	Likert scale 1-5	35	20	19	22	4
	Hawksworth 1997	144	0	144	0	"Do you feel music affects your vigilance during an anesthetic?" (negatively)	Likert scale 1-3	9.6		64.4	26	
	Narayanan and Gray 2018	101	37	29	35	Effect of music on own focus?	Likert scale 1-5 (Negative-positive)	4	13	58	25	1
						Effect of music on own vigilance?	Likert scale 1-5 (Negative-positive)	1	10	79	11	0
	Yamasaki 2016	390	99	97	194	"How does music impact your concentration?"	NRS 0-100 (Negative-positive)	Mean 59.9 (standard deviation 24.6)				
Team performance	Faraj 2014	52	27	6	8	"I feel the overall performance of the theater team is better when music is played"	Likert scale 1-5 (with 6th option: do not know)	NR Do not know: NR		NR	63	
	Narayanan and Gray 2018	101	37	29	35	Effect of music on overall team performance	Likert scale 1-5 (Negative-positive)	2	4	44	44	7
						Effect of music on mood in the OR?	Likert scale 1-5 (Negative-positive)	0	3	12	64	22

(continued)

Table 2 – (*continued*)

Domain	Study	*n*	SUR	ANA	NUR	Survey question	Assessment method	Result (%)				
								Disagree		← →	Agree	
Stress	George 2011	100	44	25	31	"Do you think it (music) reduces your autonomic reactivity in stressful surgeries?"	Likert scale 1-5	14	13	14	50	09
	Makama 2010	162	94	18	22	Does music reduce stress?	List of options (multiple options allowed)	NR		NR	91.4	
	Narayanan and Gray 2018	101	37	29	35	Effect of music on own calmness?	Likert scale 1-5 (Negative-positive)	1	8	43	46	3
	Oliver 1999	35	10	10	15	"Generally do you find it (music) relaxing?"	No, sometimes, yes (with 4th option: do not know)	11 Do not know: 11		3	74	
Distraction	Faraj 2014	52	27	6	8	"I find music played in the operating theater distracting"	Likert scale 1-5 (with 6th option: do not know)	NR Do not know: NR	NR	NR	27	
	Hawksworth 1997	144	0	144	0	"Does music distract you from alarms on the theater monitors?"	Likert scale 1-3	63.5		24	11.5	
						"If things are not going well with the anesthetic, do you find music distracting when it might not have been before?"	Likert scale 1-3	16.3		28.8	51	
	Makama 2010	162	94	18	22	Does music prevent distraction?	Multiple options	NR		NR	79.6	
	Narayanan and Gray 2018	101	37	29	35	Does music distract during a crisis?	NR	NR		NR	84	
	Ullmann	171	NR	NR	NR	Do you view music as a distracting factor when played during a long, complicated, or emergency procedure?	NR	NR		NR	20	
	Yamasaki 2016	390	99	97	194	"Do you find music distracting?"	NRS 0-100 (Not at all-very much so)	Mean 32.2 (standard deviation 22.2)				
Communication	George 2011	100	44	25	31	"Do you think music restricts your communication with other staff?"	Likert scale 1-5	42	24	6	23	5

Hawksworth 1997	144	0	144	0	"Does music affect your communication with staff in theater?" (negatively)	Likert scale 1-3	15.4		59.6	24	
Narayanan and Gray 2018	101	37	29	35	Effect of music on own communication? (Negatively)	Likert scale 1-5 (Negative-positive)	3	27	64	7	0
Ullmann 2008	171	NR	NR	NR	"Do you think that music in the OR affects communication between staff?" (negatively)	Likert scale 1-3	63		28.6	8.4	
Yamasaki 2016	390	99	97	194	"How does music impact communication between team members in the OR?"	NRS 0-100 (Negative-positive)	Mean 55 (standard deviation 22.5)				

Questions presented with quotation marks represent the exact phrasing used in the survey, while words in parenthesis have been added to clarify the question.
n = number of total survey participants; SUR = number of surgeons; ANA = number of anesthesiologists; NUR = number of OR team nurses or other members; NR = not reported; NRS = numeric rating scale.

previously conducted studies solely measured the presence of high decibel levels. However, it appears that higher noise levels during surgery are associated with an increased rate of surgical-site infections.[22,23] Although this does not infer causality, a noise reduction program can apparently significantly reduce the postoperative complication rate.[8] Recent studies revealed the auditory cortex of patients to be active and receptive during general anesthesia,[50,51] while even low noise levels in sleeping individuals affect the cardiovascular system.[2] This could theoretically explain the negative effects of high noise levels in surgical patient during general anesthesia and should be further explored in future studies.

Noise pollution in the OR is perceived negatively by the staff as well. Current noise levels are subjectively perceived to be a disturbance in the OR by over half of surveyed surgeons, anesthetists, and nurses, with the majority considering it to have a negative influence on the job.[28] Furthermore, noise can increase stress both subjectively and objectively in an already stressful environment,[8] plagued with high burnout levels.[52] Noise-induced hearing loss seems to be prevalent in 50% of OR personnel involved in orthopedic surgery.[53,54] An extensive meta-analytic synthesis of 242 studies evaluating the effects of noise in healthy adults on task performance observed significant negative effects on cognitive task performance (effects size -0.34 [95% confidence interval (CI) -0.42 to -0.25], 191 studies), psychomotor performance (-0.43 [95%CI -0.74 to -0.21], 11 studies), and communication tasks (-0.53 [95%CI -0.83 to -0.23], 17 studies).[55] These effects on task performance were not only related to noise level intensity. The presence of intermittent noise, the type of noise, and the task performed are important factors as well. Whether performance in the OR is affected by noise seems to be partially dependent on experience. Assisting surgeons with less experience report higher subjective distraction levels due to noise than the primary, more experienced surgeons.[10] The negative impact of noise on clinical reasoning was lower in more experienced anesthesiological residents.[25] Although simulated laparoscopic task performance in 12 experienced surgeons was not negatively affected by noise at 80 to 85 dB, the sample size was relatively small and the comparator was either a clinically unnatural silent or music setting.[26]

Of interest is the fact that music was not subjectively identified as a negative factor by OR staff, even though sound levels are doubled by music.[39] Therefore, it seems that not all increases in noise levels equal negative effects. Several recent extensive meta-analyses have observed beneficial effects of perioperative music on postoperative pain,[12] intraoperative sedative medication requirement,[13] postoperative opioid requirement,[13] and the physiological stress response to surgery in adult surgical patients.[14] Moreover, music reduced mental workload in novice laparoscopists and improved laparoscopic task performance in the simulated setting depending on task demand as well.[56,57] In this review, we chose to only focus on the attitudes and perception toward music in the OR. Most OR staff are positively predisposed to playing music in the OR and have attributed positive influences of music on performance, teamwork, concentration, and stress reduction. This general positivity appears to be irrespective of specialty (surgeon *versus* anesthesiologist), experience (residents *versus* attending physicians), or type of

Table 3 – Risk of bias in crossover studies.

Study	Random sequence generation	Allocation concealment	Blinding of participants and staff	Blinding of outcome assessors	Incomplete outcome addressed	Selective reporting addressed	Appropriate crossover design	Carry-over effect addressed	Unbiased data addressed	Other bias addressed
Cheriyan 2016	No	No	No	No	Unclear	Unclear	Yes	Unclear	Yes	No
Engelmann 2014	No	No	No	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
Enser 2010	Yes	Yes	No	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes
Moorthy 2004	Unclear	Unclear	No	Yes	Unclear	Unclear	Yes	Unclear	Yes	Yes
Tsafrir 2020	No	No	No	Unclear	Unclear	Unclear	Yes	Unclear	Yes	Yes
Way 2013	Unclear	Unclear	No	Unclear	Unclear	Unclear	Yes	Unclear	Yes	No

No = high risk.
Unclear = unclear risk.
Yes = low risk.
Engelmann 2014: the evaluation of staff can be classified as a nonrandomized crossover design.

health care provider (attending *versus* nurse), although the degree of enjoyment varied.[38] It appears that in clinical practice, the music played is most often selected by the senior surgeon or through a team consensus.[29,35,37] Playing music during surgery was also widely considered to be a positive influence regarding work enjoyment. Higher satisfaction with the work environment is associated with a lower chance of burnout.[58] This is a vital factor for young physicians and nurses wishing to leave their profession.[58,59] Moreover, it seems that most health care staff in the OR do not believe that music negatively affected communication or acted as a distraction. However, when a problem is encountered, the opinions regarding music differ.[29,31,35,36] Miscommunication is a major cause for the occurrence of medical errors leading to injury in surgical patients, with 30% occurring intraoperatively.[60] Clearly, music in the OR should not affect communication, but whether this is the case has to date been insufficiently investigated in our opinion. The conclusions from two studies regarding auditory perception in a simulated setting should be taken with care.[39,40] Although participants were presented with increasing levels of background noise, followed by the addition of music, it appears that the auditory message volume remained the same. Naturally, it is to be expected that the correct auditory response rate will decrease when decibel levels increase. Both studies failed to take the Lombard effect into account, a well-recognized physiological phenomenon during which speakers increase their voice level and adapt their speech manner when in the presence of increasing background noise levels.[41] A nonrandomized observational study performing a univariate analysis after dividing 20 surgical procedures of five surgeons to music *versus* no music observed a higher number of repeated requests when music was played.[11] However, we believe that multiple potential confounding factors were not adequately addressed. The use of music intraoperatively can theoretically act as a cue for creating awareness during specific situations in the OR, as lowering the music volume or turning off the music entirely during critical moments would draw the immediate attention of all surgical team members present. This would fit into the sterile cockpit concept used by the aviation industry. During specific, critical, predefined moments, all attention should be diverted to the task at hand and irrelevant conversation and music are prohibited. As surgery involves a combined team effort of surgeons, residents, anesthetists, scrub nurses, and circulating nurses, care should be taken to assess these specific phases with higher demands for each member involved in the entire surgical procedure, given the difference in specific task demand.[10]

The aim of this systematic review was to assess the effect of noise in the OR. Although many studies have reported noise exceeding recommended decibel levels, its effect on both the patient and OR staff has only been investigated to a very modest degree. Our results were limited to only presenting the previously published data. Risk of bias in accordance with standard assessment methods was considered high, but given that it is not possible to blind patients or members of the OR to noise, we do not consider this to be of influence. Given the variety of outcome measures and the differences in study design, no meta-analysis could be performed. Drawing conclusions should be taken with caution, although several

Table 4 – Risk of bias of cross-sectional survey studies.

Study	Representativeness of sample	Adequacy of response rate	Missing data in completed questionnaires	Clinical sensibility of survey	Validity of survey instrument	Other bias
Faraj 2014	Probably low risk (Random selection of all OR staff, single center)	High risk (52/121, 43%, but reported rate 58%)	Unclear (Not reported)	Probably low risk (ordered response categories)	Probably low risk (ordered response categories)	Contradicting results and figure on distraction
George 2011	Probably low risk (Random selection of all OR staff, single center)	Unclear risk (Not reported)	Low risk (100% response rate in accordance with Table 1)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable
Hawksworth 1997	Low risk (Random selection nationwide)	Probably low risk (72% response rate)	Probably low risk (Not all questions answered)	Probably low risk (Tested by colleagues)	Unclear risk (Not reported)	Only anesthetists surveyed
Kumar 2013	Low risk (Random selection of international anesthetists at conference)	Probably low risk (62% response rate)	Low risk (Above 98% completed)	Probably low risk (Previously used questionnaire)	Probably low risk (Previously used questionnaire)	Only neuro-anesthetists surveyed
Lee 2013	Low risk (Random selection of international urologists)	High risk (25% response rate)	Low risk (100% completed the online survey)	Unclear risk (Not reported)	Unclear risk (Not reported)	Only urologists surveyed
Makama 2010	Unclear risk (Not reported)	Low risk (97%, completed)	Low risk (Above 97% completed)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable
Narayanan and Gray 2018	Probably low risk (Random selection of all OR staff, single center)	High risk (45% response rate)	Low risk (Above 95% completed)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable
Oliver 1999	Probably high risk (Random sample, but limited number surveyed)	Low risk (35/45, 78% response rate)	Probably low risk (1/8 questions not completely filled out)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable
Padmakumar 2017	Low risk (Random selection of OR staff nationwide)	Unclear risk (Not reported)	Low risk (100% completed in accordance with tables)	Probably low risk (Tested by sample OR staff)	Unclear risk (Not reported)	Not applicable
Tsiou 2008	Low risk (Random selection of OR staff nationwide)	Unclear risk (Not reported)	Unclear risk (Not reported)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable
Ullman 2008	Low risk (Random selection of OR staff in three hospitals)	Probably low risk (171/250, 62% response rate)	Low risk (Above 90% completed)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable
Yamasaki 2016	Low risk (Random selection of OR staff nationwide)	Low risk (Directed survey)	Low risk (Above 99% completed)	Unclear risk (Not reported)	Unclear risk (Not reported)	Not applicable

concepts on the negative effects of noise on both the patient and performer have been presented. Because of the use of a range of nonvalidated questionnaires, the varying ways in which the questions were posed, combined with the different survey methods used, it was not considered appropriate to calculate a single overall mean result regarding the attitudes and perception toward music. Rather, we choose to present all study results individually. Nevertheless, the opinion of the health care staff seems to be in line with the view of the patient, namely that music during surgery is generally regarded to be a significant positive factor on all domains.[13] It should be noted that most surveys consisted of more general, nonspecific questions, which could be interpreted in multiple ways. Furthermore, the same questions were often posed to different specialists and nurses with the answers presented jointly, although their specific situations and work demands differ greatly.[10] Especially in regard to communication and distraction, future studies should evaluate critical phases for each member involved in the surgical procedure during which care should be taken to minimize both noise and music in the OR.

It seems apparent that not all increases in noise levels have the same effects. Although the 'sterile cockpit concept' is often mentioned, a total sound-sterile work environment in the OR seems to be neither practically possible nor desirable.

Some noise is unavoidable, given the fast-paced environment of the OR and high turnover, while proper communication is essential. Moreover, we believe that general conversation and music should be acceptable, as this increases work enjoyment in an already stressful environment and prohibiting it entirely would not be feasible. Future studies on noise in the OR should focus on patient outcome besides solely measuring decibel levels, ideally taking into account the physiological stress response or similar markers of stress. Furthermore, both reduction of specific noise sources as well as filtering out of noise during surgery should be further explored. Decreasing noise pollution levels caused by surgical instruments and alarms, which are the main noise sources in the OR,[4] can be achieved through innovative equipment design.[61] As intraoperative music has significant beneficial effects,[12] implementing music through headphones for patients during surgery would both reduce unwanted noise pollution as well as provide music. Moreover, several studies have explored the use of intraoperative microphones and headphones for the OR team as well,[24,62] especially in regard to robotic surgery during which the surgeon is often placed at a considerable distance away from the operation table. As more attention and scientific interest is increasingly payed in recent years to the health care work environment, attenuating noise pollution should also be included.

Conclusion

High noise levels in the OR seem to negatively affect both patient outcome and the surgical team. Future studies should assess whether this knowledge can be applied to benefit patient outcome and performance by the OR staff. Even though music significantly increases decibel levels in the OR, perception and attitude toward playing music during surgery is favorably regarded by most OR staff, irrespective of specialty.

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Supplementary data

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