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Assessment of noise pollution and its effect on patients undergoing surgeries under regional anesthesia, is it time to incorporate noise monitoring to anesthesia monitors: an observational cohort study

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Abstract

Background: Operating rooms (OR) are noisy places, and proper control of intraoperative noise is advised by health care organizations to avoid its hazardous effects. Finding a smartphone application to measure and control intraoperative annoying sound is necessary.

Objective: To compare noise levels in Kasr Al Ainy Hospitals' ORs with the World Health Organization (WHO) recommendations and to investigate their effects on patients.

Methods and material: Forty patients who underwent surgeries under regional anesthesia at six different theaters enrolled in this observational cohort study. Sound was recorded by TM-102 Sound Level Meter and NoiseCapture app simultaneously. They used to capture the maximum (Max) and minimum (Min) values of A-weighting and average (mean) values in decibel (dB). The 1ry outcome was a comparison of the equivalent sound pressure levels (Leq (A)) measured by TM-102 Sound Level Meter with WHO recommendation (i.e., 40 dB).

Results: Mean noise levels in different theaters were far away from the WHO recommendations. The mean (Leq (A)) level measured by TM-102 Sound Level Meter was 73.01 (± 5.74) compared to 72.15 (± 6.57) measured by NoiseCapture. These levels exceeded the WHO recommendation by around 1.8 times. Both tools showed a good correlation with no statistically significant differences in all readings. Four distressed patients (66.7%) reported the obstetric theater as the highest noisy OR (78 dB).

Conclusions: Intraoperative noise levels at Kasr Al Ainy Hospital reached critical values that exceeded the international recommendations. For intraoperative noise monitoring, NoiseCapture smartphone application appeared like a straightforward hand-held software appropriate for this purpose.

Keywords: Noise, WHO recommendations, NoiseCapture, Sound level meter

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Background

An operating room is supposed to be a quiet environment. However, this is not always the case nowadays (Murthy et al. 1995). Many types of equipment and devices can produce intraoperative noise, even the air conditioning system regarded as a common source of pollution. Intraoperative levels can reach levels above 75 dB that is higher than the recommended by the international regulations (Katz 2014). Noise levels exceeding 100 dB had reported during orthopedic surgery and neurosurgery in up to 40% of the monitored time (Kracht et al. 2007).

Excessive noise can lead to psychological and physiological effects on all health care professionals, reduce their performance and work efficiency, disturb oral communications, and increase the rates of perioperative adverse events (Braz et al. 2006). The World Health Organization (WHO) had produced guidelines in 2002 that identified specific noise levels within hospital environments. These recommendations included equivalent sound pressure levels (Leq) should not exceed 35 dB(A) during the night and 40 dB(A) during the day (Christensen 2005).

NoiseCapture is a free android software application (app) designed for measuring environmental noise using a smartphone. This app is a part of a larger project called NoisePlanet that offers many open-source noise-measurement tools. NoiseCapture app is a collaboration between two French research laboratories, the Environmental Acoustic Laboratory of Ifsttar (French Institute of Science and Technology for Transport) and the National Center for Scientific Research. The app geolocates the sound and logs the number of decibels, frequencies, date, and time of the recording. Users can also take a picture of the noise location for further evaluation (Perroud 2018).

We hypothesized that noise levels measured during surgery at different theaters in Kasr Al Ainy Hospitals probably higher than those recommended by WHO, and the use NoiseCapture could facilitate noise control.

Methods

This cohort prospective observational study conducted on forty patients scheduled for elective or urgent surgeries under regional anesthesia at Kasr Al Ainy Hospital, Cairo University, throughout 6 months duration (from Jan. 4, 2018 to Jan. 10, 2018). The study aimed to compare noise levels in Kasr Al Ainy Hospitals' ORs with the WHO recommendations, to investigate their effects on patients and to assess the feasibility of intraoperative use of NoiseCapture app.

We tried to explore all theaters at Kasr Al Ainy Hospitals, performing surgical procedures under regional anesthesia to assure adequate representation of the whole population. These theaters included the following: general, gynecology and obstetrics, urologic, trauma and emergency, ophthalmic, and orthopedic surgery operating theaters. Each operating theater was investigated and studied for a week of working days (started from Saturday to Thursday) to screen patients who met the inclusion criteria. Every morning, each patient in the operation list scheduled for surgery under regional anesthesia was given a number that is similar to his order in the list. Each number was put and concealed in a closed opaque envelope. Then, a non-research participating anesthetist was asked to choose two envelopes randomly and opened them to know the patients who screened for the inclusion criteria. If a patient who randomly chosen failed to be recruited (either due to exclusion, parallel OR admission with the 1st case, conversion to general anesthesia, or other causes), another envelope chosen randomly. In the orthopedic surgery operating theater and due to a significant variation in the sound level between different operations, we divided surgical procedures into those with high sound properties (e.g., saw and powered drills) and those with low sound properties. We tried to ensure an equal chance of representation in both types by recruiting a case for each daily.

After approval by the departmental Research Ethics Committee, we obtained informed consent from all patients before the commencement of the study. Patients of both sexes in the age group of 18–55 years, belonging to the American Society of Anesthesiologist (ASA) physical status classes I and II, had enrolled in the study. Those who underwent elective or urgent surgeries under regional anesthesia that lasted < 3 h and could rate pain on a numeric rating scale (NRS) of 0 to 10 also enrolled in this study. Patients aged < 18 or > 55 years, who had ASA class III or IV, refused to participate, non-cooperative, unable to communicate, deeply sedated, or had hearing problems were excluded from the study. Patients with difficulty in evaluating their level of pain, taking any antipsychotic medications, or those with a history of affective disorders also ruled out from the study.

Operation rooms (ORs) in Kasr Al Ainy Hospital vary in their sizes. All of the rooms have hard surfaces with no unique material added for sound absorption. Our morning lists start at 9:00 am with the 1st nursing shift, while the 2nd nursing shifts start at 1:00 pm till the end of the afternoon list. A numeric pain rating scale was explained clearly to all patients before the conduction of anesthesia, and then IV midazolam at a dose of 0.03 mg/Kg was given. After that, regional anesthesia in the form of spinal anesthesia to most of the patients and local infiltration for ophthalmic operations conducted to obtain a satisfactory surgical level of anesthesia. We used the following tools to monitor intraoperative sound levels:

1. NoiseCapture android software app version:1.1.2 Jan. 2018 r
2. TM-102 Sound Level Meter (EN61672 type 2)

NoiseCapture app calibrated according to the manufacturer's recommendation before each single use. An external microphone was attached to the smartphone of interest and fixed at the same place as the fixed sound level meter. The TM-102 Sound Level Meter comes with TM-100 Sound Level Calibrator (ANSI S1.4-1984 and IEC 942 1988 class 2). This unit conforms to the International Electrotechnical Commission's (IEC) Standard IEC 61672-1 class 2 standard, IEC651 type 2, American National Standards Institute (ANSI) S1.4 type 2 for level meters. It had designed to meet the measurement requirements of safety engineers, health, industrial safety offices, and quality control in various environments. It measures sounds from 30–130 dB with outranging at frequencies between 31.5 and 8 KHZ. Its accuracy is ± 1.5 dB. It measures both A-weighting and C-weighting in both fast (125 mS) and slow (1 s) times. The data stored in the sound level meter. Calibration of the sound level meter unit was carried out the everyday morning by the investigator, as per manufacturer's recommendations. Sound level meter placed inside each room before starting the case until the end of the case of each day. The instrument placed behind the anesthesia monitor in a safe and hidden place. By placing the monitoring equipment microphone at that place, we ensured that sound detected from different areas was uniform.

The zero time of the study was 10 min before patient admission to OR. It is time when the OR was empty, and monitors were off with no personnel or activities inside. Sound recording was started at that time by TM-102 Sound Level Meter and NoiseCapture app simultaneously to measure the background noise at first. TM-102 Sound Level Meter was used to capture the maximum (Max) and minimum (Min) values in dB of A-weighting on fast response time mode and average (mean) on the slow mode. Min, Max, and mean values were compared to that obtained by NoiseCapture. Once the patient was out of the OR, all recordings and measurements ended.

The following data recorded: patient's age and sex, time of surgery (either morning or afternoon surgery), type of operation, and duration of surgery (time in minutes from skin incision until skin closure). We recorded the name of the theater and the number of personnel present in OR at any time from patient admission until patient transfer from OR (excluding the investigator). Heart rate (HR), respiratory rate, and mean arterial blood pressure (MAP) were recorded at the following times: T_0, immediately before conduction of anesthesia; T_1, 5 min after conduction of anesthesia; T_2, 5 min after surgical skin incision; and T_3, 5 min after skin closure. Ramsay sedation scale (Sedation scales 2018): assessed and recorded 10 min after administration of regional anesthesia to ensure that the preoperative sedation did not affect the patient's perception of noise.

The following are sound parameters measured by both tools and recorded in decibels for each OR: background sound level, minimum (Min), maximum (Max), and mean (Mean) values of fast sound levels. NoiseCapture app was also used to calculate LA90 (defined as A-weighted noise level that exceeded 90% of the measurement period and used to quantify the background noise level), LA50 (defined as A-weighted noise level that exceeded 50% of the measurement period), equivalent noise level (Leq) in dB(A) on the whole measurement duration, and repartition of the noise exposure (RNE). RNE was used for percentile categorization of noise distribution over the entire recording period into five groups: group 1, ˂ 45 dB(A); group 2, 45–55 dB(A); group 3, 55–65 dB(A); group 4, 65–75 dB(A); and group 5, ˃ 75 dB(A). Data obtained by NoiseCapture app was displayed on the smartphone screen as presented in (Fig. 1).

We recorded the postoperative numeric pain rating scale (NRS) from 0 to 1 by asking the patient 10 min after discharge to the postanesthesia care unit. Also, the sedation-agitation scale (Sedation scales 2018) was recorded at 10 min after admission to the postanesthesia care unit (PACU). These two scales were computed to exclude any influence of postoperative pain or agitation on patient's recognition of noise.

At PACU, a simple verbal questionnaire (see below) was presented in the Arabic language to each patient to assess his/her noise perception in OR. Patients answered the questionnaire by either yes or no:

A. Was the OR a noisy place for you or not?

B. Were you annoyed by noise in OR?

C. Would you prefer a quitter OR?

D. Which of the following possible sources of noise made the OR a noisy place to you (if the answer of A was yes)?:

- Monitors alarms
- Placing equipment in their positions or moving it
- Operation of equipment, e.g., pneumatic/electrical saw, suction apparatuses
- Equipment beeping, e.g., surgical diathermy
- Air condition
- Staff entering or leaving or wandering around
- Shift exchanges of nursing staff
- Conversations among staff
- Shouting of nursing staff
- Opening packages

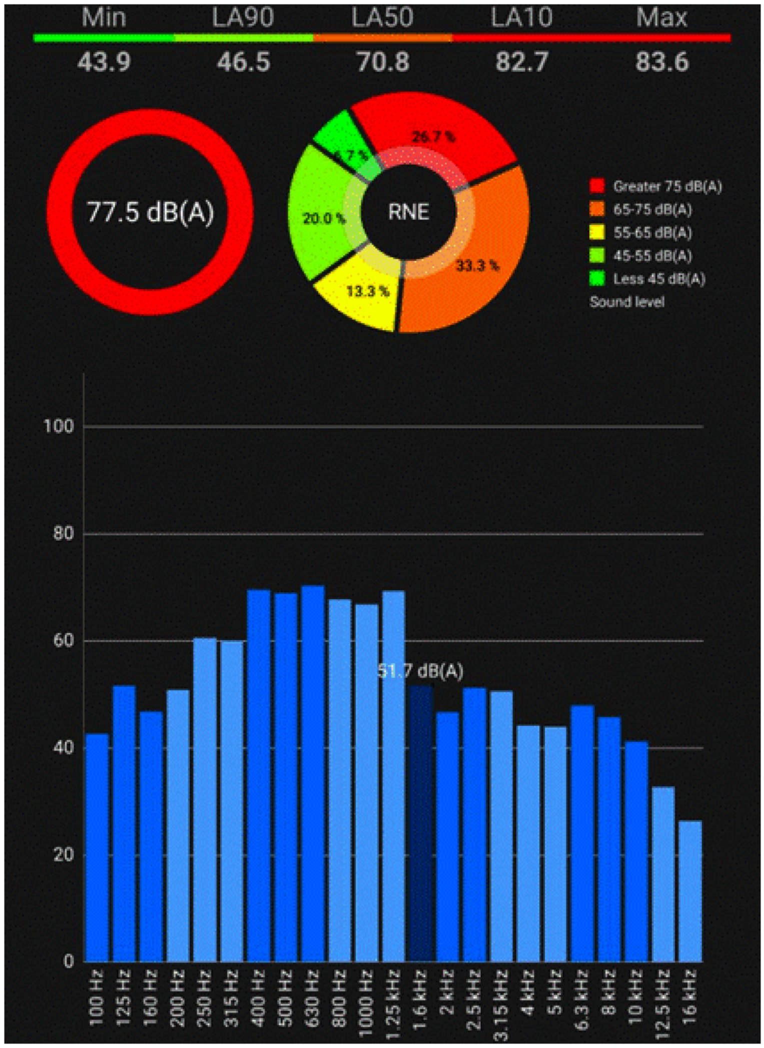

Fig. 1 Data measured by NoiseCapture app [6]. Minimum (Min), maximum (Max), mean (Mean) values of fast sound level, percentile noise levels in dB(A) over the whole measurement duration: LA90, A-weighted noise level that is exceeded for 90% of the measurement period; LA50, A-weighted noise level that is exceeded for 50% of the measurement period; LA10, A-weighted noise level that is exceeded for 10% of the measurement period; repartition of the noise exposure (RNE), used for percentile categorization of noise distribution over the whole recording period into 5 groups: group 1, ˂ 45 dB(A); group 2, 45–55 dB(A); group 3, 55–65 dB(A); group 4, 65–75 dB(A); and group 5, ˃ 75 dB(A)

The 1ry outcome of this study was to compare the equivalent sound pressure levels ((Leq (A)) measured by TM-102 Sound Level Meter in each theater with that recommended by the WHO (i.e., 40 dB). Secondary outcomes included are the following: possible sources of OR noises, how the patients perceived noise, and its effect on them, and which OR theater and type of surgery had a high level of noise. Other 2ry outcomes included categorization of noise distribution over the whole recording period, and comparison of different measured noise values between NoiseCapture app and TM-102 Sound Level Meter on different OR as measured at different days of the week and at different time of working day hours.

Statistical analysis

Data were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 25. Data were summarized using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables made using the non-parametric Kruskal-Wallis and Mann-Whitney tests (Chan 2003a). For comparing categorical data, chi-square (χ^2) analysis performed. The exact test was used instead when the expected frequency was less than 5 (Chan 2003b). Correlations between quantitative variables were done using the Spearman correlation coefficient (Chan 2003c). P values less than 0.05 were considered as statistically significant.

Results

In this study, we enrolled forty patients who fulfilled the inclusion criteria. The study performed in 6 different theaters where patients anesthetized by using regional anesthesia. Our mean patients' age was 36.83 (± 14.33) years; males were 55% of patients (n = 22), while 45% of them (n = 18) were females. The mean duration of surgery was 77.13 (± 38.30) minutes, with 55.0% of patients (n = 22) operated upon during the afternoon list, while 45% of them (n = 18) operated upon during the morning list. The mean number of personnel present during surgery was 4.05 (± 0.90) patients.

Table 1 showed patients' characteristics and operations' characteristics with no statistically significant difference between patients (P value > 0.05).

Background noise, Max, Min, and average noise levels recorded by the two devices shown in (Table 2). Results showed a good correlation (P ˂ 0.05) with no statistically significant differences between the two methods in all readings.

Intraoperative respiratory rate changes were comparable between patients with no statistical significance. In the TM-102 recordings, there was a moderate negative correlation between the average noise level and MAP after administration of regional anesthesia (T_1) and after surgical incision (T_2) (r = − 0.38, P = 0.013 and − 0.4, P = 0.010 respectively). The heart rate after administration of regional anesthesia (T_1) appeared positively correlated with noise levels (r = 0.3, P = 0.045). On the other hand, there was a moderately negative correlation between the average noise level measured by NoiseCapture and MAP after administration of regional anesthesia (T_1) and after surgical incision (T_2) (r = − 42, P = 0.006 and − 0.43, P = 0.005 respectively). The heart rate at baseline (T_0) appeared positively correlated with noise levels (r = 0.39, P = 0.047).

The mean values of both LA90 and LA50 were 61.50 (± 4.86) and 60.03 (± 7.54), respectively. Figure 2 illustrates that 39% of the measured equivalent noise level (Leq) of patients was in the range of 65–75 over the whole recording period. There was a statistically significant difference (P value ˂ 0.05) between different theaters in all measured noise levels (Min, Max, and average) in both recorded methods (TM-102 and NoiseCapture application). The mean Max level recorded by TM-102 was 97.2 ± 5.8 in the orthopedic theater which had a statistically significant difference to other theaters (P value = 0.018), while the minimum noise (MIN) recorded by TM-102 was in the ophthalmic theater with a mean value of 51.6 ± 4.6 and the P value was 0.040. Ophthalmic surgery theater had the lowest mean of average noise level (65.54 ± 5 and 63.98 ± 4 measured by both devices, respectively). There was a statistically significant difference (P value ˂ 0.05) between different theaters regarding the mean weighted noise level that exceeded 50% of the measurement period (LA 50). The ophthalmic surgery theater had the lowest value (56.78 ± 3.22), while the obstetric surgery theater had the highest value (65.27 ± 2.93), and this made a statistically significant difference (P value = 0.004). LA 90 had no significant difference between theaters. These results are evident in the following Table 3.

Results revealed no significant differences (P value ˃ 0.05) between morning and afternoon operations regarding different parameters of noise measurement as recorded by both devices. All patients were interviewed at the postanesthesia care unit and asked to answer three questions about their noise experience in the operating room. Their answers revealed that only six patients (15%) found the OR as a noisy place and preferred it to be quieter as they were distressed. They were also asked to determine the source of noise in the operating room. Answers of the questionnaire revealed that 50% of patients who found the OR as a noisy place (n = 6), concluded that conversation between staff was the principal cause of the noise (7.5%). Placing objects in their positions or moving it (5%) and shouting of nursing staff (2.5%) were the other sources of noise. There was a significant statistical significance between the patient's perception of noise and type of theater. Results revealed that 66.7% of patients who reported the noisy OR were in the obstetric theater, while 33.3% of them operated upon in orthopedic theater. Although afternoon surgeries were "noisy" to patients (n = 2, 11.10%) more than patients (n = 4, 18.20%) operated upon in the morning list, however results showed no statistically significant difference (P ˃ 0.05) between the time of surgery (morning or afternoon) and perception of noise by patients.

The mean number of persons found in OR during the study period of surgery was four persons at a time. There was a strong correlation between the number of personnel and noise levels (r = 0.54 with P ˂ 0.05 in the TM-102 group and r = 0.41 with P = 0.008 in the NoiseCapture group). Results showed a non-significant correlation (P value ˃ 0.05) between the average measured by both methods and duration of surgery. Ramsay score assessed after 5 min of induction of regional anesthesia, and its mean was 1.92 ± 0.27. Results revealed no significant statistical correlation between the average noise level and the Ramsay score (P value ˃ 0.05).

All patients (100%) had scored four on the sedation-agitation scale and zero on NRS.

Table 1 Patients' and operations' characteristics

Variable		Count (frequency)
Theater	General surgery	8 (20.0%)
	Urological surgery	7 (17.5%)
	Obstetric	6 (15.0%)
	Ophthalmic surgery	9 (22.5%)
	Emergency department	5 (12.5%)
	Orthopedic surgery	5 (12.5%)
Operation type	Anal fissure	2 (5.0%)
	Piles	1 (2.5%)
	Varicocelectomy	3 (7.5%)
	Ureteroscopy	4 (10%)
	Herniorraphy	3 (7.5%)
	Cesarean section	6 (15%)
	Varicose veins	2 (5.0%)
	Cataract surgery	5 (12.5%)
	Vitrectomy	3 (7.5%)
	Lid elevation	1 (2.5%)
	Appendectomy	2 (5.0%)
	Amputation	2 (5.0%)
	Knee arthroscopy	1 (2.5%)
	Femur pinning	1 (2.5%)
	Hip replacement	1 (2.5%)
	Tibial fixation	1 (2.5%)
	Ankelscope	1 (2.5%)
	Fournier gangrene debridement	1 (2.5%)
Distribution over days	Saturday	8 (20%)
	Sunday	6 (15%)
	Monday	8 (20%)
	Tuesday	4 (10%)
	Wednesday	7 (17.5%)
	Thursday	7 (17.5%)

Data presented as number and percentage

Discussion

This study designed to assess the noise level in the operating rooms on Kasr Al Ainy Hospitals, to compare noise levels with those recommended by WHO, and to find a simple tool to control it. To the best of our knowledge, this is the 1st study conducted on our institute to evaluate the noise issue. The noise level in hospitals should not exceed 35–40 dB during the day, as

Table 2 Correlation of readings between Tm-102 sound meter and NoiseCapture

Variable	Tm-102 sound meter (*n* = 40)	Android NoiseCapture (*n* = 40)	*P* value
Background	49.86 (± 3.02)	47.34 (± 3.15)	0.85
Max	90.85 (± 5.64)	91.09 (± 6.46)	0.861
Min	56.79 (± 4.93)	52.33 (± 5.18)	0.72
Average	73.01 (± 5.74)	72.15 (± 6.57)	0.532

Data presented as mean (± SD). *n* number, *p* probability, *Max* maximum values in dB of A-weighting on fast response time mode recorded by both devices during the study period, *Min* minimum values in dB of A-weighting on the fast response time mode recorded by both devices during the study period

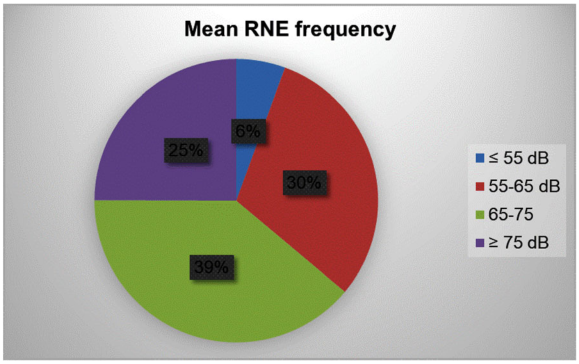

Fig. 2 Mean RNE. RNE repartition of the noise exposure, dB decibel

recommended by the US Environmental Protection Agency and WHO. Association of Australian Acoustical Consultants also recommends that background noise should be more than 30 dB(A) (Kurmann et al. 2011). The mean noise levels recorded in the six studied theaters were far away from the WHO recommendations. The recorded mean average of the equivalent sound pressure levels (Leq (A)) measured by TM-102 Sound Level Meter was 73.01 (± 5.74), and that measured by NoiseCapture was 72.15 (± 6.57). These levels exceeded those supported by WHO by around 1.8 times. All other measured noise parameters, even the minimum and background values, exceeded the 40 dB that is recommended by WHO. This higher mean of background noise level could be attributed to the air conditioning system and the proximity of many ORs in the same theater. Unfortunately, our ORs had no materials to absorb sounds. Surprisingly, we could not record any sound levels below 45 dB at any theater at any time. The most frequent average noise readings (around 39%) were ≥ 75 dB, while 30% of records were in the range of 55–65 dB. In line with the results of this study, the study done by Tsiou et al. (2008) when they assessed the level of noise pollution in many operating rooms in hospitals in Greece. And they found that the level of noise in different surgeries is very different as the mean noise level (LAeq) reached a maximum level of 71.9 dB in some operations. Nassiri et al. (2014) conducted a study to assess the level of noise pollution in some hospitals in Iran and study its effects on nurses' psychological and physiological responses. Although their surveyed locations were different from our study as they included wards interiors, the wards of emergency, maternity, infants, surgery, and burns, the outpatient waiting area and outpatient hall, however, they achieved similar results. They found that the average noise level in some hospitals was higher than the national standard in Iran (45 dB (A)). The conversations between the patients and their families and relatives were the most common noise-generating sources. Healey et al. (2007), in their study, used a Tecpel SE-322 sound-level meter (Tecpel, Taipei, Taiwan) to measure sound pressure levels in 30 urological operations. Their results showed that the mean noise levels ranged from a minimum of 51.14 dB(A) to a maximum of 63.91 dB, with an average of 56.92 (SE 0.58) dB. The average minimum noise level for an operation was 46.90 dB, and the average maximum noise level for surgery was 80.28 dB. The absolute minimum level recorded from the entire sample was 37.40 dB, and the absolute maximum was 92.60 dB.

Sound pressures differ from a type of operating theater to another. We found that the highest noise level was in the obstetric theaters with a mean noise level of around

Table 3 levels in different theaters

	General surgery	Urological surgery	Obstetric surgery	Ophthalmic surgery	Emergency surgery	Orthopedic surgery	*P* value
Background Noise	50.3 (± 3.8)	48.84 (± 3)	51.82 (± 2.7)	48.98 (± 2.6)	49.84 (± 4.3)	49.84 (± 2.4)	0.408
Max (TM-102)	90.3 (± 3.3)	91.56 (± 4.4)	90.67 (± 5.9)	85.82 (± 4.3)	93.62 (± 5.3)	97.26 (± 5.8)	0.018*
Min (TM-102)	57.2 (± 3.1)	61.64 (± 5.7)	58.35 (± 1.7)	51.67 (± 4.6)	56.16 (± 4.5)	57.3 (± 1.2)	0.04*
Average (TM 102)	71.46 (± 2.9)	73.37 (± 2.6)	77.68 (± 2.5)	65.54 (± 5)	78.82 (± 2.2)	77 (± 3.1)	< 0.001*
Max (NoiseCapture)	91.27 (± 4.1)	90.7 (± 6.1)	93.27 (± 6.5)	83.97 (± 4.2)	96.26 (± 3.6)	96.38 (± 5.5)	0.002*
Min (NoiseCapture)	52.75 (± 4.6)	51.94 (± 5.2)	53.53 (± 4.3)	47.14 (± 3.8)	57.52 (± 4)	54.92 (± 3.2)	0.007*
Average (NoiseCapture)	72.78 (± 4.9)	69.51 (± 5.3)	78.17 (± 3.9)	63.98 (± 4)	77.14 (± 1.6)	77.3 (± 1.1)	< 0.001*
LA 50 (NoiseCapture)	59.62 (± 4.59)	62.20 (± 4.10)	65.27 (± 2.93)	56.78 (± 3.22)	64.14 (± 4.73)	64.88 (± 3.49)	0.004*
LA 90 (NoiseCapture)	60.18 (± 6.29)	60.31 (± 8.31)	64.18 (± 6.00)	51.48 (± 4.58)	64.32 (± 6.19)	65.50 (± 2.37)	0.005

Data presented as mean (± SD). Max, maximum values in dB of A-weighting on fast response time mode recorded by both devices during the study period; Min, minimum values in dB of A-weighting on fast response time mode recorded by both devices during the study period; LA 90, the A-weighted noise level that is exceeded for 90% of the measurement period (a useful descriptor to quantify the background noise level); LA50, the A-weighted noise level that is exceeded for 50% of the measurement period

*Significant statistical difference

78 dB followed by orthopedic theater with a mean noise level of about 77 dB. The fact that can explain these, orthopedic theater had many instruments that could cause high sound pressure. The average noise level in the obstetric theater was slightly higher than that found in the orthopedic theater. This high sound level may be due to the more significant number of cases studied in obstetric theater (six versus five in orthopedic theater). Also, a higher incidence of side talks and conversations in the obstetric theater could be another explanation. The lowest noise level was reported in the ophthalmic theater with a mean noise level of around 65 dB. Ophthalmic theater had the favor of a quiet environment with minimally talking staff and low sound level OR instruments.

In line with the findings of this study to some extent is that done by Kracht et al. (2006) They investigated noise levels in the operating rooms of Johns Hopkins Hospital in the USA in 2006. They suggested that the mean noise level in orthopedic surgeries was higher (66 dB) when compared with the other types of operations (62–65 dB). The mean number of persons found in OR during the study period of surgery was four persons at a time. There was a strong correlation between the number of personnel and noise levels. In the TM-102 group, r was 0.54 with $P < 0.05$, while r was 0.41 with $P = 0.008$ in the NoiseCapture group. The high levels of noise detected in our study were due to the increased number of personnel in each operation as it is a teaching hospital. The study sample recruited patients that covered the whole working days of the week and also covered both nursing shifts (morning and afternoon).

Results failed to find any statistical significance correlating noise levels with either days or nursing shifts. Furthermore, results were unable to relate high sound levels to longer surgical times. An important finding in this study is the success and reliability of the android application (NoiseCapture) in gathering the sound pressure with an easy and simple interface that illustrates all parameters with graphical representation and categorization. NoiseCapture showed a high accuracy of recording and readings as values were comparable between it and Tm-102 sound meter. Ramsay score was used to assess the patient's intellectual function 5 min after the administration of regional anesthesia, that is, to ensure that the preoperative dose of sedation did not affect the patient's perception of noise. Its mean level in all patients revealed that all patients were oriented and cooperative.

The numeric pain rating scale and sedation-agitation score were used at PACU to exclude any effect of pain or sedative residuals on patients' responses to the questionnaire. All patients had a score of four on the sedation-agitation score, which means that patients were calm and cooperative postoperatively. Eighty-five percent of patients denied that the OR was noisy, although the high level of recorded sound. This percent could be explained by the low educational status of these patients, or they live in places with a high level of noise, and so they did not get annoyed anymore. Both patients and hospital staff benefit from a quiet environment. In a calm environment, fatigue and mental stress of health team staff reduced, and patients do not suffer from physiological and psychological stresses, and their well-being improves. In a study conducted by Sener et al. (2010) in 2010 in Turkey, the effect of noise on the anxiety of patients who underwent surgery studied. They stated that increased level of noise causes increased tension in patients, whereas background noise, especially music, can reduce the anxiety of patients. West et al. (2008), conducted research to assess noise pollution in the operating rooms of some US hospitals. They stated that many people's hearing accuracy reduced with an increase in staff conversation errors. Finally, researchers report that it is necessary to use appropriate acoustic materials in the operating rooms to reduce noise pollution.

This study has many limitations: the small sample size, the time consumed in the calibration processes of both Tm-102 sound meter and NoiseCapture software, and we failed to link specific events, such as the use of a bone saw, to the observed high sound pressure levels. Also, in our study, we could not follow patients for 24 h after surgery to record postoperative noise complications as well as we did not study the effect of noise on OR personnel.

So, it is recommended to repeat the study on a broader range of operations and larger sample size and to use the NoiseCapture app. for construction of "noise maps" for Kasr Al Ainy Hospitals.

Conclusion

Intraoperative noise levels at Kasr Al Ainy Hospital reached critical values that exceeded the international recommendations. Many strategies and policies should be implemented to improve and change their current status. Intraoperative noise monitoring can be added to anesthesia monitors to enhance patient safety. NoiseCapture smartphone application is a handheld and straightforward software that appeared appropriate for this purpose.

Abbreviations

ANSI: American National Standards Institute; app: Application; ASA: American Society of Anesthesiologist; IEC: International Electrotechnical Commissions; IFFSTAR: French institute of science and technology for transport; LAeq: Equivalent A-weighted continuous sound level; Leq: Equivalent continuous sound level; Max: Maximum; Min: Minimum; NRS: Numeric rate pain scale; OR: Operating room; PACU: Postanesthesia care unit; *P* value: Probability value; RNE: Repartition of noise exposure; SPSS: Statistical package for special science; WHO: World Health Organization

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Authors' contributions
H.M. developed the idea and the design of the study. A.H., A.G, and H.M. carried out the implementation, data collection and analysis. A.H. and H.M took the lead in writing the manuscript. S.B, A.H, A.G. and H.M. performed literature search, manuscript preparation and revision. All authors read and approved the final manuscript before submission.

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Availability of data and materials
Data supporting findings can be obtained from the corresponding author.

Ethics approval and consent to participate
Local ethics approval committee has been obtained, and written informed consent has been obtained from all patients enrolled in the study. This study had been approved by the Research Ethics Committee, Department of Anesthesia, Faculty of Medicine, Cairo University.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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