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**Sound and vibration: effects on infants' heart rate and heart rate variability
during neonatal transport**

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Short title: Sound, vibration and stress during neonatal transport

ABSTRACT

Aim: To measure the effect of sound and whole-body vibration on infants' heart rate and heart rate variability during ground and air ambulance transport.

Methods: Sixteen infants were transported by air ambulance with ground ambulance transport to and from the airports. Whole-body vibration and sound levels were recorded and heart parameters were obtained by ECG signal.

Results: Sound and whole-body vibration levels exceeded the recommended limits. Mean whole-body vibration and sound levels were 0.19m/s^2 and 73dBA, respectively. Higher whole-body vibration was associated with a lower heart rate ($p<0.05$), and higher sound level was linked to a higher heart rate ($p=0.05$). The heart rate variability was significantly higher at the end of the transport than at the beginning ($p<0.01$). Poorer physiologic status was associated with lower heart rate variability ($p<0.001$) and a lower heart rate ($p<0.01$). Infants wearing earmuffs had a lower heart rate ($p<0.05$).

Conclusions: Sound and whole-body vibration during neonatal transport exceed recommended levels for adults and sound seem to have a more stressful effect on the infant than vibrations. Infants should wear earmuffs during neonatal transport because of the stress reducing effect.

Key-words: heart rate variability, neonatal transport, sound, stress, whole-body vibration

Key Notes: We have measured effects of sound and whole-body vibration on heart rate and heart rate variability on infants transported by air and ground ambulance. Sound and vibration during neonatal transport exceeded the recommended limits for adults. Neither sound nor whole-body vibration had an effect on heart rate variability, but high sound levels seems to cause a higher heart rate indicating a stressful effect on the infant while high vibration did not.

INTRODUCTION

Transportation of critically ill infants requires specific skills, ongoing training, well developed routines and unique equipment to minimize the effects of several risk factors that might be present (1). Among all risk factors that are incorporated in neonatal transports, the effects of whole-body vibration (WBV) and sound levels on the infant during transport are inadequately studied. In adults WBV can cause irritability, fatigue, blurred vision, shortness of breath, chest and/or abdominal pain, increased metabolism, adverse effects on the cardiovascular and respiratory systems, motion sickness and vomiting (2).

Previous studies on WBV during neonatal transport have measured accelerations and peak levels, but the effect of these parameters on the infant have to our knowledge not been described. Macnab et al. (3) showed that vibration during neonatal transport exceeded the maximum recommended limit (0.31m/s^2) for adults (4) and suggested that this level should not be exceeded during neonatal transport since there are no available standards for infants.

Sound levels during neonatal transport have been shown to greatly exceed the International Electrotechnical Commission (IEC) standard recommendation for maximum sound levels ($<60\text{dBA}$) inside the transport incubator (5).

It has been shown that high sound levels in the neonatal intensive care unit (NICU) adversely affect infants, resulting in cochlear damage, disruption of normal growth and development of premature infants (6) and probably sleep disturbance, irritability, fatigue and general discomfort. Both risk factors, sound and WBV, should be taken in account because of their potentially detrimental effects on the infant (3). Therefore it is reasonable to assume that critically ill infants may also be adversely affected by exposure to these risk factors during transport (7). It is important to describe the effect of sound and WBV on the transported infant and to undertake measures to reduce such noxious influences.

The aim of the present study was to measure the effects of sound and WBV on the infant's heart rate (HR) and heart rate variability (HRV) during ambulance and air ambulance transport.

METHODS

Study subjects

Sixteen transports, carried out by the Neonatal Transport Team (NTT) of the Department of Pediatrics at the University Hospital in Umeå, Sweden, were included in the study. Infants who were enrolled in the study were transported in a transport incubator (Dräger 5400) lying on a foam mattress. The infants were restrained in a 'nest' against the mattress base. The transported infants' mean age was 17 days (SD 25 days), with a mean GA at birth of 33 weeks + 0 days (SD 3 w + 6 d). The infants' mean weight was 2507g (SD 1289g). Transport mean length was 2 hours and 30 minutes (SD 39min). The infants' diagnoses/indications for transport were as follows: abdominal surgery, 4 (25%); cardiac surgery, 3 (19%); prematurity, 4 (25%); respiratory disease, 1 (6%), and back transport to community hospital, 4 (25%). Six (38%) infants needed respiratory support by a ventilator, two (13%) infants needed nasal continuous positive airway pressure, four (25%) infants breathed spontaneously and received supplemental oxygen, and four (25%) infants were on air, breathing spontaneously. Earmuffs were attached on 10 infants during the complete transport. Ordinary Swedish ground ambulance models and air ambulances stationed in Umeå (Beechcraft King Air 200) were used.

Measurement equipment and data collection

The infant's exposure to sound in the frequency range 2-3500Hz was measured with a ½-inch microphone (Microtech Gefell GmbH, Gefell, Germany) installed on the upper part of the incubator wall 10-20cm from the infant's head. The microphone was directed toward the centre of the incubator in order to avoid measurement errors due to audio interference with the incubator roof and walls.

WBV with frequencies up to about 100Hz were measured with a tri-axial accelerometer (ST Microelectronics LIS3L06AL, Geneva, Switzerland) on the surface under the infant's foam mattress. The WBV were measured in three directions (x, y, z), in accordance with ISO standard 2631-1 (4). To record the infant's electrocardiogram (ECG) we used an output from the patient monitoring device (Propaq Encore®, Welch Allyn Inc, New York, USA). The microphone, the accelerometer and the ECG signal from the patient monitor were connected to a data acquisition device. The data acquisition unit included preamplifiers, analog-to-digital converter, microprocessor and a secure digital memory card for data storage. Sound and WBV levels were continuously recorded throughout the transport. The infant's sound and WBV exposure levels were determined for the entire transport and for predefined sections of the transport cycle (Table 1). Sound level data were presented in terms of dBA and dBI values, the former in accordance with current Swedish provisions and recommendations and international standards for noise (8) and the latter as an un-weighted level for low-frequency noise within the range of 2-20Hz (infrasound). The corresponding levels of exposure to WBV are specified in the form of frequency-weighted sum vector acceleration values ($\text{m/s}^2_{\text{rms}}$) in accordance with ISO 2631-1 (4).

Transport risk index of physiologic stability (TRIPS)

The status of the infant prior to and after the transport was assessed by TRIPS (9). TRIPS consist of four clinical variables (temperature, blood pressure, respiratory distress and response to noxious stimuli), and total score can range from 0 to 65. In this present study critically ill infants with poor physiologic status were defined as having a TRIPS score of 20 or higher, while less ill infants were defined as having a TRIPS score of 10 or lower.

Procedure

Registration began shortly before the transport incubator started moving at the referring hospital and ended when the transport incubator stopped at the receiving hospital. To simplify

analysis and interpretation, the 12 sections were merged into 3 transportation divisions: before flight (sections 1-4), flight (sections 5-8) and after flight (sections 9-12), (Table 1).

Heart rate variability

HRV was analysed based on automatically detected heart beats in a single-channel ECG recording. Spurious arrhythmic beats and detection errors were removed by automatic filtration of the R-R interval data, where R-R intervals were automatically removed if they differed more than 15% in relation to the mean of the preceding and following R-R intervals (10). The R-R interval data were transformed into an evenly sampled (2.4Hz) heart rate time series by cubic spline interpolation. For each of the specified sections of the recording as described in Table 1, the mean HR and the variance (HRV) were calculated. The recording and analysis software was developed at the Department of Biomedical Engineering, at the University Hospital in Umeå, Sweden.

Statistical analysis

Repeated analysis of variance (ANOVA) measurements were used to investigate changes over time for the variables in simple models, with only the categorical variable section in 12 measurements as independent variable. If the assumption of sphericity was not fulfilled the method of Greenhouse and Geisser was used for calculating the p-values. To analyse the impact of explanatory variables on the heart variables HR and HRV, simple and multiple linear regression models were performed. Due to the design of the study, with repeated observations for individual infants (each infant was measured in each section), an exchangeable correlation structure was assumed and the parameters were estimated by generalized estimating equations. The normality assumptions for the dependent variables were checked with histograms. The significance level 0.05 was used for all analyses.

RESULTS

Mean values and standard deviation for measured variables determined for all transport sections and divisions are presented in Table 1. The average HRV was lowest in the first

division and highest in the last division while the average HR was highest in the first division and lowest in the last division. There were no significant changes in HR over time during the transportation, but for HRV significant changes over time were found ($p < 0.05$). The most significant differences were found between sections 3 and 12 and sections 4 and 12. Table 2 shows the duration of exposure to different sound and WBV levels. While in flight the average sound level exceeded 70dBA during 99% of the time during flight the average sound level is >70 dBA and 64% of the time. Vibrations during taxi before takeoff were greater than 0.31m/s^2 during 64% of the time.

The mean WBV level throughout the transport (i.e. sections 1-12) was 0.19m/s^2 . The mean WBV level was below 0.31m/s^2 in all sections, except section 6 (0.37m/s^2). In section 5 the mean WBV levels were lowest (0.08m/s^2). Table 3 shows peak values in each section for WBV, sound and infrasound. There were WBV peaks exceeding 0.97m/s^2 in every section and the highest peak WBV was 3.9m/s^2 and in section 9. During ground transport (i.e. sections 3 and 10) the WBV exposure were dominated by frequencies within the range of about 3-8Hz. The WBV frequency characteristics of the air transport (section 7) was however different. The dominant WBV frequencies were in range of about 125-135Hz and below about 1-2Hz. The former is most likely vibration caused by the aircraft engines and the latter is low frequency oscillation of the aircraft due to changes in outside air pressure. The sound levels were higher during flight than any other part of the transport ($p < 0.001$). The average sound level throughout the transport was 73dBA. In sections 1 and 2, the mean sound level was below 60dBA. The average sound level was highest in section 7 (78dBA) and lowest in section 1 (57dBA). There were sound peaks exceeding 87dBA in every section and the highest sound peak was 100 dBA and in section 3 and the lowest sound (45dBA) was measured in section 10. Significant changes over time were also found for the variables dBA, dBI and WBV ($p < 0.001$). Associations between the heart variables (HR and HRV) and explanatory variables (dBA, dBI, WBV), TRIPS (high/low), earmuffs (yes/no) and

transportation division were analysed in simple and multiple linear regression models estimated with generalized estimating equations. The heart variables HR and HRV were judged sufficiently normally distributed for the analysis. Analysis of HR showed that significant variables in the simple regressions were WBV ($p<0.05$), TRIPS ($p<0.01$) and earmuffs ($p=0.05$). Analysis of HRV showed that significant variables in the simple regressions were TRIPS ($p<0.001$) and transportation division ($p<0.01$). Two models using multiple regressions were used, including variables with p-values in the simple regressions below 0.2 (model 1) and 0.05 (model 2), respectively. The reason for also choosing the limit 0.2 when selecting variables for the multiple regressions is the relatively small sample and the possibility that effects of interest could be missed out if only the limit 0.05 was used. The multiple regressions for HR (model 1 and model 2) showed that higher WBV was associated with lower HR ($p<0.05$, $p<0.05$), higher TRIPS score was associated with lower HR ($p<0.01$, $p<0.01$) and use of earmuffs was associated with lower HR ($p<0.01$, $p<0.01$). Model 1 showed that higher dBA was associated with higher HR ($p=0.05$). The multiple regressions for HRV (model 1 and model 2) showed that higher TRIPS was associated with lower HRV ($p<0.001$, $p<0.001$) and that the last transportation division had higher HRV values than the first transportation division ($p<0.01$, $p<0.01$). No infants had a TRIPS score between 10 and 20.

DISCUSSION

Decreased HRV has been correlated to stress in infants while increased HRV indicates a status of greater well-being of the infants (11). It has also been shown that higher morbidity and mechanical ventilation cause reduction in HRV (12,13). In the present study the total HRV increased significantly over time during the transport, suggesting that at the end of the transport the infants were less stressed and more stable. However, we could not find any correlation between HRV and changes in WBV levels. The accelerometer was fastened in the incubator directly under the mattress, and in theory, a vibration-dampening effect of the foam

mattress on which the infant was lying cannot be excluded. However, this appears unlikely, since it has been shown that foam mattresses, like the one we used, do not attenuate vibration (14). In contrast, in adults an experimental model with constant acceleration amplitude and variable vibration frequencies showed an influence in HRV (15) and another showed that hand transmitted vibrations lead to decreased HRV (16). HRV has been used as a tool for detecting pain of shorter duration in infants (17), but may not be an optimal parameter for measuring stress from sound or WBV during longer periods. In the present study we could not show that WBV had an effect on HRV, but higher WBV amplitudes were linked to a lower HR, indicating that the vibrations experienced by the infants were not stressful.

High mean sound levels, exceeding 60dBA, prevailed during most of the transport. There was no effect of high sound levels on HRV but HR increased. Similar to our results another study showed no relation between HRV and background noise at a level of 48-50dB inside an incubator in an NICU environment (18). In contrast, white noise of 85dBA increases the HRV in adults (16). Since sound and hand transmitted vibrations in adults have opposite effects on HRV, sound and WBV in this study could cancel out the effects on the infants' HRV. Higher HR has been used as a marker of stress or pain in infants (17) and infants are stressed when exposed to sound stimuli in the NICU environment (19). Our study corroborates these results in a neonatal transport setting. The fact that the use of earmuffs (reducing sound levels at least 7dB) was significantly associated with a lower heart rate further strengthens the importance of minimizing sound stimuli during transport. In the NICU, as well, the use of earmuffs can stabilize oxygen saturation levels and increase sleeping periods (20). The reduction of sound in the low-frequency area, sound covered by dBI, was likely marginal. Further reduction of sound levels could probably be accomplished by developing a more efficacious sound reduction in the low frequency area. To conclude, higher mean WBV was associated with lower HR, indicating a soothing effect on the infant, whereas higher mean sound levels increased the HR as a sign of stress.

TRIPS is a validated tool for infant assessment during transport (9). We found that a high pre-transport TRIPS score was linked to a lower HRV, in accordance with earlier studies showing lower HRV in infants with more severe illness, ventilator treatment and sedative treatment (12, 13).

We found in accordance with earlier studies that the sound and WBV levels to which the infants were exposed exceeded recommended limits for adults. However, in particular, results from vibration studies may be difficult to compare because of differences in equipment, design, vehicle, and measuring points. Macnab et al. (3) found that the highest WBV levels during transport by a comparable aircraft was 0.86m/s^2 . In our study, the highest peak value during flight was 2.8m/s^2 , which occurred during turbulence and bad weather conditions. In only one of the transports we found a flight peak WBV value below 0.86m/s^2 . On the other hand, the mean WBV values in our study are comparable with the values found by Macnab et al (3). As earlier mentioned the exposure to WBV was dominated by acceleration levels at very low frequencies (below about 1-2 Hz) and at high frequencies (above 100 Hz). A WBV exposure at low frequencies, and in particular z-axis vertical vibration in the frequency range 0.1 to 0.63 Hz, is known to be particularly critical for developing motion sickness (21). The sensitivity to develop motion sickness varies with age, and it is well known that children develop symptoms more easily compared with elderly. However, most infants younger than 18 months, such as those transported in this study, do not develop symptoms of motion sickness (21).

There have been studies of various interventions to reduce WBV during neonatal transport, but the effect on the infants' well-being was not elucidated (22). Accelerations exceeding 0.31m/s^2 are generally perceived as uncomfortable (4). Mean levels of WBV during transport exceeded 0.31m/s^2 only during taxiing before takeoff. The average length of this section was only 3 minutes; thus, the infants were not exposed to these WBV for an extended period of time. During ambulance transit from the airport, the mean WBV levels were 0.30m/s^2 , almost

exceeding the recommended level. The mean length of this section was over 19 minutes, so the infants were exposed to these WBV for a relatively long period of time. The mean WBV levels measured during ground ambulance transport in this study are similar to levels recorded in a recent study (23). Even though the mean WBV levels were below 0.31m/s^2 during most of the transport, they exceeded 0.31m/s^2 36% and 46% of the time during ground ambulance transfer to and from the airport, respectively. In all other sections they exceeded 0.31 m/s^2 between 4% and 26% of the time. WBV in the ‘fairly uncomfortable zone’ (i.e. $0.63\text{-}1.0\text{m/s}^2$) (5) occurred between 0% and 9% of the time, most often in the first and last divisions, showing that during flight the WBV are fairly low. The peak WBV level measured in the study occurred during a transfer from air ambulance to ground ambulance measuring 3.9m/s^2 . Information and training of the personnel involved could probably reduce the risk of high WBV during transfer between the different vehicles. Even when the transport incubator is transferred within the hospital, WBV could probably be reduced by personnel being extra careful when rolling over thresholds, especially in and out of elevators (24). Driving style may also affect WBV levels (25), and it is also important to avoid roads that are in poor condition. When developing new transport incubators, there should be more efforts made to reduce transmission of WBV.

The average sound level during the whole transport was almost 73dBA, clearly higher than the current recommendation of the IEC standard (5). The average sound levels presented in earlier studies are comparable with our results (3, 26). The sound levels were higher during flight than any other part of the transport. This was also the section that had the longest mean duration, 64 minutes. Being in flight exposes the infant to high sound levels for a relatively long period of time; therefore, it is reasonable to put focus on reducing sound levels during this part of the transportation. A recent study reported no reduction in sound levels inside the transport incubator after covering it with cell-foam (26). The consequent use of earmuffs

(MiniMuffs®, Natus Medical Inc, Seattle, USA) seems to be a simple method to reduce the sound levels at least 7dBA as specified by the manufacturer..

The average sound level in the first two sections was below 60dBA. Although the mean sound levels were lower than the recommended 60dBA, the mean length of these sections was only about 7% of the length of the total transport. The average sound level during ambulance transit to and from the airport was 64 and 65dBA respectively, and similar to a recent study (23). Yet, the highest sound peak measured in this study was during ambulance transit (100dBA), indicating that smooth handling and driving are of utmost importance for reducing peaks and overall sound levels. Watts et al. (27) even recommended avoiding sirens whilst in the ambulance and setting mobile phones to vibration mode.

No earlier studies have shown how infants are physiologically affected during transport. Premature infants may especially be influenced by high or changing sound and WBV levels. A weakness of this present study is the heterogeneous study cohort varying in gestational age at birth and postnatal age, factors known to influence HR and HRV in response to stress (11). On the other hand the use of TRIPS score allowed us to evaluate the infants according to severity of illness. Other feasible instruments available to measure stress during transport, are saliva cortisol levels and skin conductance measurements. Sound and vibration may also have other unfavorable effects on the infants' physiological status. In future studies we plan to add skin conductance as a tool for measuring stress in infants during transport. Another extension is to compare the physiological response of the infant during fixed-wing and rotor-wing aircraft transport. Helicopters are widely used for neonatal transport and the exposure to WBV and sound in this environment has not only a different character but also in most cases at considerably higher levels (3, 23). Further studies are thus required to find practical tools for assessing stress during neonatal transport, with the ultimate goal to reduce or eliminate strain on the vulnerable infant.

CONCLUSION

Sound and whole-body vibration during neonatal transport exceed recommended levels for adults. Higher sound levels were found to be associated with a higher heart rate, which may reflect stress on the infant. Higher vibration levels were however associated with a lower heart rate. A high sound level seems to constitute a more significant problem compared with vibration during neonatal transport. Heart rate variability increased significantly over time during transport suggesting a more stable and less stressed infant, but neither sound nor vibration affected the heart rate variability. Infants should wear earmuffs during neonatal transport because of the stress-reducing effect. Infants with higher pre transport TRIPS score had a lower heart rate and heart rate variability.

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ABBREVIATIONS

ANOVA	Analysis of variance
dBA	A-weighted sound levels
dBI	Unweighted infrasound levels (2-20Hz)
ECG	Electrocardiogram
GA	Gestational age
HR	Heart rate
HRV	Heart rate variability (total spectral power)
IEC	International Electrotechnical Commission
NICU	Neonatal intensive care unit
NTT	Neonatal transport team
TRIPS	Transport risk index of physiologic stability
WBV	Whole-body vibration

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Table 1. Mean values and standard deviation (in parentheses) for measured variables determined for all transport sections and divisions

Transport Section	Transport Division	Duration Minutes	Cum. duration Minutes	Sound dBA	Infrasound dBI	WBV m/s ²	HR bpm	HRV mHz ² , log
1. Transit from ward to ambulance	1	8.1 (5.1)	8.1 (5.1)	58 (5.9)	72 (6.1)	0.18 (0.18)	145 (29)	2.80 (0.31)
2. Loading into ambulance	1	1.8 (0.5)	9.9 (5.1)	59 (6.2)	73 (9.0)	0.16 (0.18)	144 (27)	2.59 (0.22)
3. Ambulance transfer	1	19.5 (7.7)	29.4 (8.5)	64 (6.1)	89 (9.1)	0.25 (0.17)	143 (27)	2.53 (0.35)
4. Loading into air ambulance	1	5.5 (1.8)	34.9 (8.5)	61 (6.3)	75 (7.3)	0.21 (0.23)	144 (29)	2.51 (0.37)
1-4. Before flight				62 (6.0)	86 (8.3)	0.23 (0.07)	143 (28)	2.55 (1.03)
5. Wait inside air ambulance during engine startup	2	8.0 (3.4)	42.9 (8.9)	64 (7.6)	80 (8.7)	0.08 (0.09)	143 (27)	2.64 (0.31)
6. Taxiing on runway before takeoff	2	2.8 (0.7)	45.6 (9.0)	73 (2.0)	88 (2.8)	0.37 (0.13)	141 (24)	2.54 (0.26)
7. Take off, flight, landing	2	64.2 (30.0)	109.8 (28.3)	78 (2.6)	78 (4.5)	0.14 (0.13)	140 (24)	2.63 (0.42)
8. Taxiing on runway after landing	2	6.3 (5.0)	116.1 (29.5)	67 (8.0)	86 (7.2)	0.20 (0.15)	141 (25)	2.69 (0.29)
5-8. Flight				77 (4.2)	81 (5.5)	0.12 (0.03)	142 (24)	2.63 (1.03)
9. Loading into ambulance	3	5.3 (2.0)	121.3 (29.7)	63 (7.2)	83 (8.0)	0.20 (0.23)	144 (25)	2.73 (0.33)
10. Ambulance transfer	3	19.4 (9.8)	140.8 (36.6)	65 (6.0)	91 (8.2)	0.30 (0.18)	141 (24)	2.73 (0.35)
11. Transfer from ambulance to trolley	3	2.2 (0.8)	143.0 (36.7)	68 (8.2)	74 (8.8)	0.21 (0.23)	142 (26)	2.76 (0.27)
12. Transit from ambulance to ward	3	6.8 (5.1)	149.8 (36.1)	65 (6.2)	73 (6.1)	0.17 (0.17)	143 (23)	2.95 (0.36)
9-12. After flight				65 (6.4)	89 (8.1)	0.27 (0.09)	141 (24)	2.71 (1.15)
1-12. Total transport				73 (5.6)	86 (7.5)	0.19 (0.03)	142 (24)	2.63 (1.06)

Table 2. Description of Sound and Whole-body vibration (WBV) in the different transport sections

Transport Section	Duration (S,D)	Cumulative duration (S,D)	dBA 0 - 60 Duration (%)	dBA 60 - 70 Duration (%)	dBA 70 - 80 Duration (%)	dBA >80 Duration (%)	WBV 0 - 0.31m/s ² Duration (%)	WBV 0.31-0.63m/s ² Duration (%)	WBV 0.63-1.0m/s ² Duration (%)	WBV > 1.0m/s ² Duration (%)
1. Transit from ward to ambulance	8.1 (5.1)	8.1 (5.1)	6 (74)	2 (24)	0 (2)	0 (0)	7 (84)	1 (13)	0 (2)	0 (1)
2. Loading into ambulance	1.8 (0.5)	9.9 (5.1)	1 (66)	1 (29)	0 (4)	0 (1)	2 (87)	0 (9)	0 (2)	0 (2)
3. Ambulance transfer	19.5 (7.7)	29.4 (8.5)	9 (44)	9 (44)	2 (11)	0 (1)	13 (64)	6 (31)	1 (4)	0 (1)
4. Loading into air ambulance	5.5 (1.8)	34.9 (8.5)	3 (60)	2 (32)	0 (7)	0 (1)	4 (74)	1 (19)	0 (6)	0 (1)
5. Wait inside air ambulance during engine startup	8.0 (3.4)	42.9 (8.9)	4 (51)	3 (32)	1 (17)	0 (0)	8 (96)	0 (4)	0 (0)	0 (0)
6. Taxiing on runway before takeoff	2.8 (0.7)	45.6 (9.0)	0 (0)	1 (20)	2 (79)	0 (1)	1 (31)	2 (64)	0 (5)	0 (0)
7. Take off, flight, landing	64.2 (30.0)	109.8 (28.3)	0 (0)	1 (1)	50 (78)	14 (21)	59 (92)	4 (6)	1 (2)	0 (0)
8. Taxiing on runway after landing	6.3 (5.0)	116.1 (29.5)	2 (39)	2 (27)	2 (34)	0 (0)	5 (77)	1 (22)	0 (1)	0 (0)
9. Loading into ambulance	5.3 (2.0)	121.3 (29.7)	2 (47)	2 (40)	1 (10)	0 (3)	4 (79)	1 (16)	0 (4)	0 (2)
10. Ambulance transfer	19.4 (9.8)	140.8 (36.6)	6 (33)	10 (53)	2 (12)	0 (2)	10 (54)	7 (37)	1 (7)	0 (2)
11. Transfer from ambulance to trolley	2.2 (0.8)	143.0 (36.7)	1 (56)	1 (32)	0 (6)	0 (6)	2 (76)	0 (17)	0 (5)	0 (2)
12. Transit from ambulance to ward	6.8 (5.1)	149.8 (36.1)	5 (74)	1 (19)	0 (4)	0 (3)	6 (84)	1 (13)	0 (2)	0 (1)

* Results are presented as mean duration in minutes, with standard deviation in parentheses, for duration and cumulative duration. Sound and WBV are presented as mean length in minutes with percentage of total mean section duration in parentheses.

Table 3. Peak values for Whole-Body Vibration, Sound (dBA) and Infrasound (dBI) levels in the different transport sections

Transport Section	WBV (m/s²)	Sound (dBA)	Infrasound (dBI)
1. Transit from ward to ambulance	1.84	88	105
2. Loading into ambulance	2.22	91	121
3. Ambulance transfer	2.30	100	121
4. Loading into air ambulance	1.67	93	120
5. Wait inside air ambulance during engine startup	1.40	87	120
6. Taxiing on runway before takeoff	0.97	96	100
7. Take off, flight, landing	2.82	99	112
8. Taxiing on runway after landing	1.71	88	110
9. Loading into ambulance	3.90	93	123
10. Ambulance transfer	2.85	97	121
11. Transfer from ambulance to trolley	2.58	94	121
12. Transit from ambulance to ward	1.79	91	106