The impact of noise exposure in Air Force Military

Original Article

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Abstract

Introduction: Military aviation is characterized by multiple noise sources, which are worrying as they exceed the legal limits required. The objective of this study is to evaluate the need to extend the monitoring program for all military exposed to aviation noise in the Air Force Units, with the specific objectives of evaluating the noise level to which they are exposed during the day and assessing the impact which it has on their quality of life.
Material and Methods: In the first phase, a retrospective study was carried out on the noise measurements taken place on Air Force Units, using sound level meters and dosimeters. Next, a cross-sectional observational study was carried out, using a questionnaire survey to the military exposed to noise, about the impact of that exposition on their quality of life. The sample of 112 military was divided in three groups: permanent and temporary aircrew staff and maintenance staff.
Results: The sound pressure levels in most of the aircraft studied proved to be higher than the limits permitted by law. Through the evaluation of the survey, it was found that the three groups had similar results, suggesting that the quality of life of military personnel is affected in the same way by noise, regardless of their functions.
Conclusions: The results justify a reflection on the way in which the assessment of noise is made and support the implementation of an evaluation and follow-up program that includes all military personnel exposed to aeronautical noise

Keywords: Aviation noise; Sonotraumatic deafness; Air crew staff; Maintenance staff; Hearing conservation program.

Introduction

Noise-induced hearing loss, also known as traumatic hearing loss, is highly prevalent in the general population. People working in military aviation are no exception, as they are exposed to multiple noise sources in their working environment, both inside and outside

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the aircraft.[1] A review of the impact of noise on the hearing of military personnel revealed that at the end of 2012, tinnitus (9.7%) and hearing loss (5.8%) were the two most common occupational diseases among United States veterans.[2] In addition to individual health concerns, hearing loss can affect the military organizations by reducing productivity and increasing absenteeism due to disability, along with shaving socioeconomic consequences.[3]

All sounds exhibit different physical parameters that, when associated with individual susceptibility, are fundamental factors in the onset of noise trauma.[4] Higher frequencies are the most aggressive to the ear, as is the case with aircraft engines and some tools used in repair and maintenance workshops.[5] The physiological defense mechanisms of the inner ear against noise progressively deteriorate with prolonged, repetitive, and frequent exposure. However, short-term exposure to a more intense sound can be just as harmful as long-term exposure to a less intense sound.[6]

In Portugal, the legislation regulating occupational exposure to noise is outlined in Decree-Law No. 182/2006, published on September 6 in the Diário da República.[7] This decree establishes the limit of noise exposure and the upper (danger threshold) and lower action values (alarm threshold), in addition to proposing a series of measures to be applied when these values are reached or exceeded. The law defines three levels of intervention:

- Exposure limit range: $L_{EX,8h}$ = 87 dB (A) or L_{Cpeak} = 140 dB (C)
- Upper action range (danger threshold): $L_{EX,8h}$ = 85 dB (A) or L_{Cpeak} = 137 dB (C)
- Lower action range (alarm threshold): $L_{EX,8h}$ = 80 dB (A) or L_{Cpeak} = 135 dB (C)

Currently, in the Portuguese Air Force (FAP), all aircrew have to undergo regular evaluation of their hearing acuity. Permanent aircrew (PAC), such as pilots and navigators, undergo annual evaluation, while temporary aircrew (TAC), including rescuers, nurses, physicians, and flight mechanics, are examined every two years. However, frontline maintenance personnel (MP) are not included in this evaluation and do not undergo audiometric testing unless they present with symptoms. The only base where a hearing conservation program is implemented for all military personnel exposed to excessive aircraft noise is Air Base no. 5, in Monte Real. This program includes audiometric evaluations for both aircrew and non-aircrew personnel exposed to the noise of the F-16 aircraft.

Considering the limited studies on this subject and the hypothesis that MP experience significant noise exposure, regardless of the aircraft type, this study aims to justify the implementation of an evaluation and follow-up program for all military personnel exposed to aircraft noise in all Air Force units. The specific objectives are to determine the noise levels in the work environment in some Air Force units, assess the impact of noise on the quality of life of MP, and evaluate factors such as the length of exposure, associated symptoms, and effectiveness of preventive measures already in place.

Materials and methods

The study began with a retrospective analysis of noise measurements made at the FAP flight squadrons, both inside and outside the aircraft in service. The data, provided by the Air Force General Inspectorate, include measurements from the C-130 and EH-101 aircraft in 2006 and the C-295M aircraft in 2014, all obtained at Air Base no. 6, in Montijo. This dataset includes measurements from both fixed and rotary wing aircraft. Air Base no. 5, in Monte Real, was excluded from this analysis as it already has a hearing conservation program for all military personnel. The analyzed parameter was the sound pressure level in decibels (dB), corrected for human hearing using the A-weighting system (dBA), obtained through sound level meters and dosimeters.

The second phase of the study involved a cross-sectional observational analysis based on the administration of a questionnaire to the PAC, TAC, and MP assigned to the squadrons

mentioned in the first phase. The same population was evaluated at the 101 squadron in Sintra, which operates the Epsilon TB-30 fixed-wing aircraft, and the 552 squadron in Beja, which operates the AW-119 Koala rotary wing aircraft. A convenience sample was obtained, divided into three equivalent groups based on the noise exposure to avoid sampling bias. The questionnaire (Appendix A), adapted from the technical report "Occupational Exposure to Noise and Vibrations in Civil Construction" by Paulo Estragadinho from the University of Minho (2006)[3], collected demographic and occupational data, as well as information on symptoms associated with noise exposure. The questionnaire was administered from August 6 to 26, 2019, using Google Forms, and the data were statistically analyzed using the SPSS® software version 22.0 .

Results

Noise measurements of PAC and TAC inside the C-130 during a round-trip flight between Lisbon and the Azores, collected using a dosimeter, revealed sound pressure levels ranging from 90.6 to 99.9 dBA. The loadmaster was exposed to the highest sound pressure levels, followed by the co-pilot and flight mechanic (Table 1).

In the EH-101, sound pressure levels ranged from 91.8 to 97.8 dBA, with the highest level recorded for the flight mechanic during takeoff and landing (Table 2). In addition to measurements inside the aircraft, a sound level meter was used outside the aircraft during pre-flight procedures, positioned to the front right, immediately after the propeller's range. Sound pressure levels ranged from 83.9 to101.3 dBA, depending on whether one or more engines was running (Table 3). These measurements were attributed to the MP group. Further measurements were conducted in the C-295M aircraft during an engine test, with the PAC and TAC inside the aircraft performing a set of procedures (Table 4). The sound level ranged from 72.1 to 95.2 dBA, and the $L_{EX,8h}$ was calculated as 74.8 dBA. The second measurement was also conducted during an engine test, but with the MP outside the aircraft (Table 5). In this case, the values ranged from 86.1 to113.0 dBA, with the $L_{EX,\ 8h}$ calculated as 99.3 dBA.

The questionnaires were distributed to the entire target population, comprising 441 members of the PAC, TAC, and MP from the selected squadrons. This yielded a convenience sample of 112 individuals and a response rate of 25.4%. All questionnaires were fully completed by the included individuals (Table 6).

The majority of participants were PAC, representing approximately 50.9% of the sample, followed by TAC (26.8%) and MP (22.3%). Most participants were men (N = 106, 94.6%), with only six women (5.4%).

Table 1
Noise measurements with a dosimeter inside the C-130 during a Lisbon-Azores-Lisbon trip on May 30, 2006

Function	Activity	Length (h)	L_{Eq} dBA	MaxP dB
Loadmaster (TAC)	Pre-flight procedures	8	99,9	146,3
	+ trip to Azores		98,0	
	+ trip to Lisbon		98,5	
Flight mechanic (TAC)	Trip to Azores	8,5	91,5	135,0
	+ trip to Lisbon		92,3	
Navigator (PAC)	Trip to Azores	8,5	90,6	127,6
	+ trip to Lisbon		90,8	
Co-pilot (PAC)	Trip to Azores	8	92,7	132,1
	+ trip to Lisbon		92,2	

L_{Aeq} = equivalent continuous sound level, in dB, determined during a daytime, evening, or nighttime period.[8]
MaxP = maximum peak value of the amplitude reached.[8]PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

Table 2
Noise measurements with a dosimeter inside the EH-101 during a training flight on July 12, 2006

Function	Length (h)	L_{Aeq} dB (A)	MaxP dB
Mechanic (TAC)	3	97.8	148.4
Systems operator (TAC)	3	93.6	136.3
Pilot (PAC)	3	93.6	136.3
Co-pilot (PAC)	3	91.8	132.7

L_{Aeq} = equivalent continuous sound level, in dB, determined during a daytime, evening, or nighttime period.[8]
MaxP = maximum peak value of the amplitude reached.[8]PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

Table 3
Noise measurements with a sound level meter outside the EH-101 during pre-flight procedures on March 8, 2006

Description	L_{Aeq} dB (A)	MaxP dB
APU engine on	83.9	119.1
APU and M1 engines on	94.4	119.6
APU, M1, and M3 engines on	98.4	124.3
APU, M1, M3, and M2 engines on	98.4	124.3
APU, M1, M3, and M2 engines and propeller on	101.3	129.0

APU = auxiliary power unit; L_{Aeq} = equivalent continuous sound level, in dB, determined during a daytime, evening, or nighttime period.[8] MaxP = maximum peak value of the amplitude reached.[8]

The average age of the population was 34.2 years (20–56 years, SD = 7.1), with a higher prevalence of individuals aged 28 and 31 years (10.7% each) (Figure 1).

In all three groups, when asked about their daily noise exposure at work, the majority (51.8%) reported being exposed to noise for 1–4 hours per day. This included 61.4%, 46.7%, and 36.0% of the PAC, TAC, and MP, respectively. The TAC had the highest percentage of longer exposure durations, with 40% reporting 4–8 hours of daily exposure and 3.3% exceeding 8 hours a day. The MP followed, with 36% exposed for 4–8 hours and 4.0% for more than 8 hours (Table 7). Most of the sample had been in their squadron for 1–5 years (33.9%) or 5–10 years (31.3%), with 25.9% having served for more than 10 years. TAC members showed the longest permanence in this category (53.3%) (Table 8). Regarding previous exposure to noise in other workplaces at the FAP, most participants reported having been exposed (69.6%) (Table 9). Concerning the use of hearing protection, the majority of PAC (57.9%) and TAC (63.3%) reported that they "always" used hearing protection. In contrast, most MP (52%) stated that they "sometimes" used personal protective equipment (Table 10).

Table 4
Noise measurements inside the C-295M during an engine test

Measured inside the C-295M for 21 minutes							
Period	1°	2°	3°	4°	5°	6°	7°
Time (min)	5	2	2	3	2	5	2
Engine Operating regime	First Engine start	Second Engine start	GROUND -IDLE	FLIGHT -IDLE	MAX -AUTO	FLIGHT -IDLE	GROUND -IDLE
Sound level (dBA)	72,1	81,6	81,8	88,1	95,2	90,1	81,9
Sound exposure level with $L_{EX,8h}$ calculation in dBA during the engine test							**74,8**

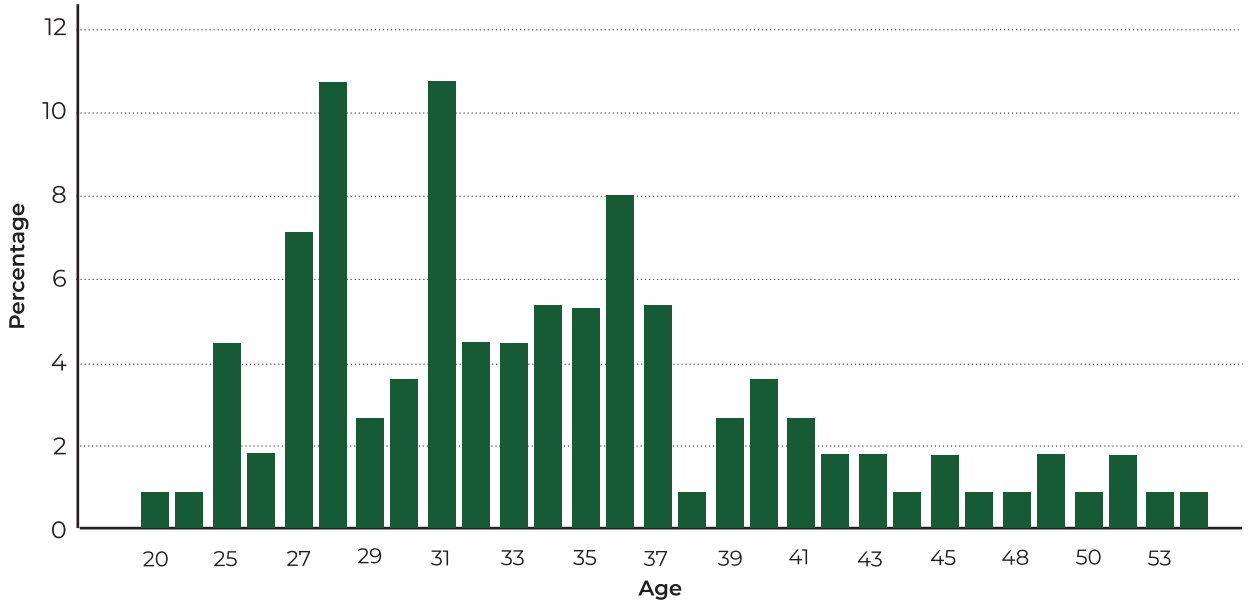
Table 5
Noise measurements outside the C-295M during an engine test

Measured outside and in the front part of the C-295M for 45 minutes							
Period	1°	2°	3°	4°	5°	7°	22°
Time (min)	1	1	4	4	5	2	2
Engine Operating regime	First Engine start	Second Engine start	GROUND -IDLE	FLIGHT -IDLE	MAX -AUTO	REAVERS	Desligar motores
Sound level (dBA)	86,1	100,1	102,1	107,7	113,0	112,9	97,9
Sound exposure level with $L_{EX,8h}$ calculation in dBA during the engine test							**99,3**

Table 6
Comparative analysis of the total and sample populations

Squadrons	Population				Sample			
	PAC	TAC	MP	TOTAL	PAC	TAC	MP	TOTAL
101 - Roncos	16	0	59	75	11	0	3	14
501 - Bisontes	36	16	44	96	1	1	0	2
502 - Elefantes	51	36	17	104	15	6	2	23
751 - Pumas	40	12	48	100	12	9	2	23
552 - Zangões	19	16	31	66	18	14	18	50
TOTAL	**162**	**80**	**199**	**441**	**57**	**30**	**25**	**112**

Figure 1
Age distribution of the sample



The analysis of symptoms potentially related to excessive noise exposure (Table 11) showed that the most common issues reported across the three groups were increased fatigue or stress (74.1%), insomnia (difficulty falling asleep or waking up) (61.6%), and irritability (58%). Tinnitus was present in 60%, 45.6%, and 44.0% of the TAC, PAC, and MP, respectively. Most MP (80%) and part of the TAC (46.7%) were already trained in hygiene and safety at work.

Table 7
Daily noise exposure by the occupational group

On an average, how long are you exposed to noise during a work day?						
		< 1h	1 a 4h	4 a 8h	> 8h	TOTAL
PAC	Frequency	12	35	9	1	**57**
	%	21,1%	61,4%	15,8%	1,8%	**100,0%**
TAC	Frequency	4	14	11	1	**30**
	%	13,3%	46,7%	36,7%	3,3%	**100,0%**
MP	Frequency	7	9	8	1	**25**
	%	28,0%	36,0%	32,0%	4,0%	**100,0%**
TOTAL	Frequency	**23**	**58**	**28**	**3**	**112**
	%	**20,5%**	**51,8%**	**25,0%**	**2,7%**	**100,0%**

PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

Table 8
Time in the squadron by the professional group

How long have you been at your workplace?						
		< 1 year	1–5 years	5–10 years	> 10 years	TOTAL
PAC	Frequency	5	22	22	8	**57**
	%	8,8%	38,6%	38,6%	14,0%	**100,0%**
TAC	Frequency	1	6	7	16	**30**
	%	3,3%	20,0%	23,3%	53,3%	**100,0%**
MP	Frequency	4	10	6	5	**25**
	%	16,0%	40,0%	24,0%	20,0%	**100,0%**
TOTAL	Frequency	**10**	**38**	**35**	**29**	**112**
	%	**8,9%**	**33,9%**	**31,3%**	**25,9%**	**100,0%**

PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

However, only about half of the participants had received training specifically on noise and hearing protection (Table 12).

Discussion

Our findings support the hypothesis that MP are significantly exposed to noise, reinforcing the need for an evaluation and follow-up program for all military personnel exposed to aircraft noise in the Air Force units. Regarding noise measurements, there is a notable lack of recent studies on some of the aircraft currently in use by the FAP. In the measurements from 2006, both the C-130 and EH-101 aircraft showed sound pressure levels exceeding the legal limit of 87 dBA, with readings surpassing 90.6 dBA and 91.8 dBA, respectively. The highest sound pressure levels in the C-130 were recorded in the cargo compartment area (99.9 dBA), where the loadmaster (TAC) operates. While these noise levels often affect PAC and TAC inside the aircraft, MP working outside the aircraft during takeoff and landing are also at risk. Sound pressure levels measured outside the EH-101 ranged from 83.9–101.3 dBA. For the C-295M, measurements showed a $L_{EX,8h}$ of 74.8 dBA inside the aircraft and 99.3 dBA outside.

According to Portuguese legislation[7], personal exposure levels must remain below 87 dBA ($L_{EX,8h}$). In this study, all measured values, both inside and outside the aircraft, exceeded these limits. Consequently, measures to either eliminate noise at its source or reduce it to safe levels should be implemented. In addition,

Table 9
Previous exposure to noise in other workplaces

Have you ever been exposed to noise at another workplace at the FAP?				
		No	Yes	TOTAL
PAC	Frequency	16	41	**57**
	%	28,1%	71,9%	**100,0%**
TAC	Frequency	6	24	**30**
	%	20,0%	80,0%	**100,0%**
MP	Frequency	12	13	**25**
	%	48,0%	52,0%	**100,0%**
TOTAL	Frequency	**34**	**78**	**112**
	%	**30,4%**	**69,6%**	**100,0%**

FAP, Portuguese Air Force; PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

Table 10
Hearing protection use by group

Do you use hearing protection?						
		Never	Rarely	Sometimes	Always	TOTAL
PAC	Frequency	3	6	15	33	**57**
	%	5,3%	10,5%	26,3%	57,9%	**100,0%**
TAC	Frequency	0	1	10	19	**30**
	%	0,0%	3,3%	33,3%	63,3%	**100,0%**
MP	Frequency	1	3	13	8	**25**
	%	4,0%	12,0%	52,0%	32,0%	**100,0%**
TOTAL	Frequency	**4**	**10**	**38**	**60**	**112**
	%	**3,6%**	**8,9%**	**33,9%**	**53,6%**	**100,0%**

PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

Table 11
Hearing symptoms by group

In the past year, have you ever experienced:					
		PAC	TAC	MP	TOTAL
Difficulty hearing certain sounds?	**No**	70,2%	50,0%	52,0%	**60,7%**
	Yes	**29,8%**	**50,0%**	**48,0%**	**39,3%**
Tinnitus?	**No**	54,4%	40,0%	56,0%	**50,9%**
	Yes	**45,6%**	**60,0%**	**44,0%**	**49,1%**
Gastrointestinal disorders?	**No**	63,2%	60,0%	76,0%	**65,2%**
	Yes	**36,8%**	**40,0%**	**24,0%**	**34,8%**
Irritability toward other people?	**No**	38,6%	50,0%	40,0%	**42,0%**
	Yes	**61,4%**	**50,0%**	**60,0%**	**58,0%**
Greater than usual fatigue?	**No**	28,1%	20,0%	28,0%	**25,9%**
	Yes	**71,9%**	**80,0%**	**72,0%**	**74,1%**
Difficulty concentrating?	**No**	49,1%	53,3%	48,0%	**50,0%**
	Yes	**50,9%**	**46,7%**	**52,0%**	**50,0%**
Insomnia (difficulty falling asleep or waking up)?	**No**	40,4%	36,7%	36,0%	**38,4%**
	Yes	**59,6%**	**63,3%**	**64,0%**	**61,6%**

PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

Table 12
Frequency of training actions

Have you ever attended any type of training related to:					
		PAC	TAC	MP	TOTAL
Hygiene and safety?	**No**	73,7%	53,3%	20,0%	**56,3%**
	Yes	**26,3%**	**46,7%**	**80,0%**	**43,8%**
Noise?	**No**	59,6%	56,7%	48,0%	**56,3%**
	Yes	**40,4%**	**43,3%**	**52,0%**	**43,8%**
Hearing protection?	**No**	59,6%	50,0%	52,0%	**55,4%**
	Yes	**40,4%**	**50,0%**	**48,0%**	**44,6%**

PAC, permanent aircrew; TAC, temporary aircrew; MP, maintenance personnel.

noise attenuation measures or reduced exposure time should be implemented in areas where noise levels exceed the upper action thresholds. This study has some limitations, including the small number of aircraft analyzed, outdated measurements, and the lack of data from other locations, such as maintenance areas. However, the results indicate that the noise limits established by law are being exceeded, leading to significant noise exposure of MP. The second phase of this study involved the administration a questionnaire to a convenience sample of 112 military workers, with a response rate of 25.4%, which is not representative of the target population. The sample was divided into three groups, PAC, TAC, and MP, based on their role within the squadron, to identify significant differences regarding the impact of noise on their quality of life, while also assessing the duration of exposure, associated symptoms, and preventive measures.

Although statistical analysis was not feasible due to the small sample size, there were no significant differences between the groups in terms of daily personal exposure to noise at work. This finding suggests that MP could be included in the regular hearing evaluation program currently in place for PAC and TAC. If the noise levels and length of exposure are similar across these groups, hearing health assessments should be also extended to all military personnel.

Most PAC and TAC reported "always" using hearing protection in the workplace, whereas the majority of MP stated that they used it only "sometimes." This suggests two possibilities: a lack of training of MP on hearing protection and occupational safety, or insufficient access to personal protective equipment. Notably, 80% of MP reported receiving general training on workplace hygiene and safety, while only 52% received training specifically on noise and hearing protection. However, not all the MP are directly exposed to aircraft noise, as some work in offices or areas away from the hangar. These individuals did not report using hearing protection, which may have influenced the overall results. When examining symptoms potentially related to noise exposure in the past year, the most commonly reported symptoms in all groups were greater-than-normal fatigue or stress (affecting 71.9% of PAC, 80% of TAC, and 72% of MP), insomnia (59.6% of PAC, 63.3% of TAC, and 64% of MP), and irritability 61.4% of PAC, 50% of TAC, and 60% of MP). These results suggest that noise has a significant impact on the quality of life of military personnel, regardless of their specific duties, justifying the need to reevaluate how their hearing health is monitored.

Another important limitation of the second phase of the study was the small sample size, which was inadequate for conducting a statistically significant analysis. However, this study serves as a valuable starting point for expanding the noise exposure evaluation and follow-up program for military personnel in the FAP. The objectives of this program include educating and raising awareness among individuals and their supervisors about the importance of using personal protective

equipment; developing noise maps to identify the areas causing noise-induced trauma; and characterizing them based on the noise intensity, frequency range, and temporal distribution during work hours, along with conducting periodic audiometric evaluations to identify individuals susceptible to noise exposure and facilitate the early detection of hearing loss.

Conclusion

Frontline military MP are exposed to noise levels exceeding the legal limits. Furthermore, their quality of life appears to be similarly affected by noise exposure as that of PAC and TAC. This highlights the need for an evaluation and follow-up program for all military personnel exposed to aircraft noise, including MP, and even civilians from other areas exposed to these noise sources. We propose an expanded hearing conservation program that includes education and awareness of personal protective measures, noise mapping, and periodic audiometric testing of all individuals exposed to noise. The aim is to identify those who are more susceptible to noise exposure and enable the early detection of hearing loss, including noise-induced hearing loss.

Conflict of Interests

The authors declare that they have no conflict of interest regarding this article.

Data Confidentiality

The authors declare that they followed the protocols of their work in publishing patient data.

Human and animal protection

The authors declare that the procedures followed are in accordance with the regulations established by the directors of the Commission for Clinical Research and Ethics and in accordance with the Declaration of Helsinki of the World Medical Association.

Privacy policy, informed consent and Ethics committee authorization

All the processed data were based in published reports that fulfilled privacy policy and ethical considerations.

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Scientific data availability

There are no publicly available datasets related to this work.

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