Correlation of Clinical and Ultrasound Findings in Infants with Hydrocephalus

Kingsley Chukwuemeka Obilo [1], Uzoamaka Rufina Ebubedike[1], Kenneth Chukwudi Eze[1], Jude-Kenndy Chinedu Emejulu[2], Eric Okechukwu Umeh[1], Charles Oshevire Ayara[3].

[1]Department of Radiology, Nnamdi Azikiwe University Teaching Hospital Nnewi, Nigeria. [2] Department of Surgery, Nnamdi Azikiwe University Teaching Hospital Nnewi, Nigeria. [3] Department of Anatomy, College of Medicine and Health Sciences, Bingham University Karu.

ABSTRACT

Background: Clinical examination and ultrasonography have been found useful in the assessment of patients with hydrocephalus. There is a paucity of data on the correlation between ultrasound and clinical findings in infants with hydrocephalus. **Objectives:** To determine and correlate the clinical and ultrasound findings in infants with hydrocephalus. **Materials and Methods**: This is a cross-sectional study of 50 patients with hydrocephalus aged 1-12 months carried out from May 2021 to January 2022 in the Radiology Department of a tertiary hospital in Nnewi. Informed consent was obtained from the subject's parents or guardians. Transfontanelle ultrasound was carried out on the infants through the anterior fontanelle using a curvilinear transducer with multiple frequencies. Data analysis was done using Statistical product and service solutions (SPSS) version 20.0 (Chicago Illinois, USA). **Results:** Out of 50 infants with hydrocephalus, the largest number 21 (42.0%) were between the ages of 1-2 months. There were more males 35 (70.0%) than females 15 (30.0%). The most common clinical features were the abnormal increase in head circumference 48 (96.0%) and the separation of sutures 47 (94.0%). The commonest ultrasound findings were aqueductal stenosis 20 (40.0%) and obstruction at the level of foremen of Luschka and Magendie 19 (38.0%). There was a significant correlation between clinical findings and ultrasound diagnosis for irritability, vomiting, poor sucking, dull response to the environment, refusal of feeds, fever, lower and upper extremity weakness, and seizures ($p<0.005$, for all). **Conclusion:** This study revealed a significant correlation between the clinical and radiological diagnosis of hydrocephalus in infants.

Keywords: Ultrasound, Clinical, Infants, Hydrocephalus

INTRODUCTION

Hydrocephalus is excess collection of cerebrospinal fluid (CSF) in the ventricles of the brain and spinal cord due to excess production, obstruction of its flow or inadequate drainage.[1,2] It can be due to impaired absorption or overproduction (rare) of CSF. Impaired absorption can be due to blockage of CSF flow within the ventricular system or blockage of arachnoid villi/lymphatic channels of cranial nerves, spinal nerves, adventitia of cerebral

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***Correspondence:**
Dr Uzoamaka Rufina Ebubedike Department of Radiology Nnamdi Azikiwe University Teaching Hospital Nnewi, Nigeria
***Tel**: 08035389501*
Email:
amakaukah@yahoo.com

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vessels.[3] The two main functional divisions of hydrocephalus are obstructive (non-communicating) and non-obstructive (communicating) hydrocephalus.[4] Patients with hydrocephalus can be asymptomatic or symptomatic. The clinical presentations include progressive increase in head circumference, tension and bulging of the fontanelles, separation of sutures, engorgement of the scalp venous channels, dwarfing of the face by a large head, sunset appearance of the eyes, irritability, somnolence, poor sucking, general obtundation (dull response to the environment), lower and upper-extremity weakness, abnormal posturing, seizures, apnea and coma.[5,6] In infants the diagnosis of hydrocephalus can be made by ultrasound where specific causative lesions such as Dandy-Walker or arachnoid cysts may be demonstrated or the level of obstruction identified.[7] Ultrasound has proven to be accurate and reliable in detecting and grading of hydrocephalus and is ideally suited to following progress. Brain ultrasound screening may also help in early diagnoses of rare lesions.[8] The mean width of the lateral ventricle in the full-term infant is 12 mm, measured at the level of the body of the lateral ventricle.[7] It is measured from the falx cerebri to the most lateral extent of the lateral ventricle. The trigone and occipital poles of the ventricles are generally the largest part of the entire ventricular system. Early dilatation is often most prominently featured in the trigone, occipital and temporal horns.[9] Studies have shown that common ultrasound findings in patients with hydrocephalus include ventriculomegaly, aqueductal stenosis, encephalocele, cerebral infarct, cerebral abscess, arachnoid cysts, hypoplasia of the corpus callosum, echogenic sulci, ventriculitis and subdural empyema. Other imaging modalities that can be used in evaluation of the infant's brain include plain radiography, conventional tomography, computed tomography and magnetic resonance imaging. Of all these imaging modalities, plain radiography, conventional and computed tomography employ ionizing radiation. Although ultrasound may not be the best imaging modality for this condition, it is the safest, cheapest and most easily available modality.

This study aims to determine and correlate the ultrasound and clinical findings in infants with hydrocephalus. The result of this study will help determine the baseline data of the common clinical findings in infants with hydrocephalus in our environment and will also help in their clinical management. Furthermore, it will help when counselling their parents about the outcome of these problems.

MATERIALS AND METHOD

Study Design

This is a cross sectional study that was conducted at the Radiology and Neurosurgery

Departments of the Nnamdi Azikiwe University Teaching Hospital, Nnewi Anambra State, Nigeria. This study which received ethical approval and clearance from the Ethical Committee of the hospital lasted for nine months. An informed, written and signed consent was obtained from each of the subject's parents or guardians prior to data collection. Patient's confidentiality was maintained.

A total of 50 infant patients referred to the Radiology Department from the Paediatrics and Neurosurgery outpatient Departments of the Nnamdi Azikiwe University, Nnewi Anambra State was recruited into the study. These patients first presented at the Paediatrics and Neurosurgery outpatient clinics where history was taken and clinical examinations done by a paediatrician and a neurosurgeon with clinical suspicion of hydrocephalus in them. They were then referred to the radiology department for transfontanelle ultrasound evaluation. At the radiology department, the subject's parents and guardians were informed about the nature of the study and a written consent obtained. In addition to the information provided by the pediatricians and the neurosurgeons, further information was sought for

from the parents. All the clinical information was documented. The consenting subjects were examined with ultrasound scan through the anterior fontanelle.

Technique

These patients were scanned using an Aloka Prosound SSD 2500 SX (2007) ultrasound machine with curvilinear transducer with multiple frequency of 2-5.5 MHz and colour Doppler capability. Patient lay supine and coupling gel applied to the area of the anterior fontanelle. The transducer was placed on the coupling gel and the six coronal images obtained. The transducer was turned to 90 degrees clockwise and the three sagittal images obtained. Following the satisfactory acquiring of these images, the gel was cleaned up and procedure ended.

Hydrocephalus was diagnosed when the diameters of the occipital horn and body of the lateral ventricles exceed 16 mm and 3 mm respectively on sagittal views. On coronal views, the third ventricle should be less than 2 mm in widest diameter.[10] On coronal view, when the fourth ventricular width and length exceed 14.3mm and 10.6mm respectively. The width of the fourth ventricle is the distance between the lateral recesses and forms the base of the triangle, posterior to which is the cerebellar vermis. The length of the fourth ventricle is the distance from the base to the apex, which is the end of the cerebral aqueduct.[11] All infants between the age of 0 and 12 months with open anterior fontanelle who have hydrocephalus and whose guardians gave informed written consent were included in this study. Children above 12 months and also those with closed anterior fontanelle were excluded.

Statistical product and service solutions (SPSS) version 20.0 (Chicago Illinois, USA) for windows software was used for data analysis. Frequency distribution and two-way tables were used to summarize the data. Fisher's exact test and Chi-square (x2) were also used to determine the association between independent and dependent variables. P value of <0.05 was considered significant. The anterior fontanelle serves as acoustic window for imaging the infant brain.[12] Also direct imaging with ultrasound can be done through the membranous temporal bone of the skull.

Lateral ventriculomegaly with associated significant thinning of cerebral parenchyma, third ventricle dilatation and normal fourth ventricle highly suggests an obstruction at level of aqueduct of Sylvia. [13]

Dilatation of all components of the lateral ventricles, third ventricle and fourth ventricle suggest obstruction at the level of the exit foraminae of the fourth ventricle.(Foramina of Luschka and Magendie)

Ventriculitis was seen as thickened, irregular and echogenic ependyma, with intraventricular echogenic debris and septae formation.[14]

Cerebral abscess seen as well-defined hypoechoeic area with hyperechoeic rim. Hyperechoeic septae and echogenic debris can be seen within abscess cavity

Choroid plexus mass seen as enlarged choroid plexus (>3.2mm in lateral ventricle and 2.5mm in fourth ventricle) with altered echogenicity, may be hypoechoeic area with regular or irregular margin within the echogenic choroid plexus.[15]

Roof of fourth ventricle mass seen as uniform or mixed echogenic, well defined mass at the apex of the fourth ventricle.

RESULTS

Transfontanelle ultrasound was performed on a total of 50 infants with hydrocephalus, aged 1-12 months. Out of these 50 infants, 21 (42.0%) were between the ages of 1-2 months and 12 (24.0%) between 3-4 months.

Table 1: Age distribution of participants

Age (months)	Frequency (%)
1-2 months	21 (42.0)
3-4 months	12 (24.0)
5-6 months	8 (16.0)
7-8 months	4 (8.0)
9-10 months	0 (0.0)
11-12 months	5 (10.0)
Total	50 (100.0)

The age group with the lowest incidence of hydrocephalus was 7-8 months, consisting of 4 patients (8.0%), no patient was seen between 9-10 months (Table 1).

The gender distribution in this study showed that there were more males 35 (70.0%) than females

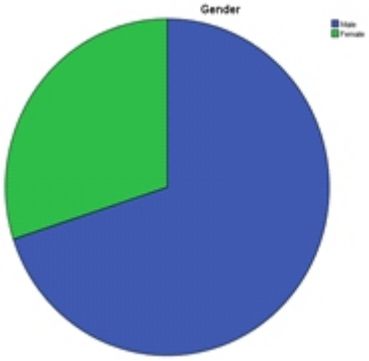

Fig 1

The most common clinical features in this study are abnormal increase in head circumference 48 (96.0%), separation of sutures 47 (94.0%) and tension and bulging of the fontanelles 36 (72.0%). Poor sucking 7 (14.0%), dull response to the environment 6 (12.0%), seizures 6 (12.0%), refusal of feeds 5 (10.0%) and lower and upper extremity weakness 2(4.0%) were the least common. (Table 2)

Table 2: Clinical findings in infants with hydrocephalus

Clinical Findings	Frequency (%)
Abnormal increase in head circumference	48 (96.0)
Separation of sutures	47 (94.0)
Tension and bulging of the fontanelles	36 (72.0)
Engorgement of scalp venous channels	14 (28.0)
Dwarfing of the face by a large head	14 (28.0)
Sunset appearance of the eyes	14 (28.0)
Irritability	13 (26.0)
Fever	11 (22.0)
Vomiting	10 (20.0)
Poor Sucking	7 (14.0)
Seizures	6 (12.0)
Dull response to the environment	6 (12.0)
Refusal of feeds	5 (20.0)
Lower and upper extremity weakness	2 (4.0)

Table 2

Out of 50 patients, 9 (18.0%) presented with communicating hydrocephalus while 41 (82.0%) presented with non-communicating hydrocephalus Table 3).

Table 3 Table showing types of hydroceph alus by ultrasonic diagnoses

Ultrasound findings	Frequency (%)
Communicating hydrocephalus	9 (18.0)
Non-communicating hydrocephalus	41 (82.0)
Total	50 (100.0)

The commonest ultrasound diagnosis were aqueductal stenosis 20 (40%), foramina of Luschka and Magendie obstruction 19 (38%) and ventriculitis 8 (16%). The least ultrasound diagnosis were cerebral abscess, choroid plexus mass and roof of 4th ventricle mass, one (1) patient each (2%) (Table 4).

Table 4 : Ultrasound diagnosis in infants with hydrocephalus

Ultrasound diagnosi s	Frequency (%)
Communicating	**9 (18.0)**
Ventriculitis	8 (16.0)
Cerebral abscess	1 (2.0)
Non-communicating	**41 (82.0)**
Foramina of Luschka and Magendie obstruction	19 (38.0)
Aqueductal stenosis	20 (40.0)
Roof of 4th ventricle mass	1 (2.0)
Choroid plexus mass	1 (2.0)
Total	50 (100.0)

Irritability, vomiting, poor sucking, dull response to the environment, refusal of feeds, fever, lower and upper extremity weakness and seizures showed P-values <0.05 (Table 5).

Table 5: Correlation of clinical findings and ultrasound diagnosis in infants with hydrocephalus

Diagnosis		Diagnosis (n=50)							
	Total (%)	Choroid plexus mass	Foramen of Luschka and Magendie obstruction	Roof of 4th ventricular mass	Ventriculitis	Aqueductal stenosis	Cerebral abscess	χ^2-value	p-value
Progressive increase in head circumference									
Absent	2 (4.0)	0	0	0	0	2 (10.0)	0	3.125	0.681
Present	48(96.0)	1 (100)	19 (100)	1 (100)	8 (100)	18 (90.0)	1 (100)		
Tension and bulging of the fontanelles									
Absent	14(28.0)	1 (100)	7 (36.8)	0	1 (12.5)	5 (25.0)	0	5.128	0.400
Present	36 (36.0)	0	12 (63.2)	1 (100)	7 (87.5)	15 (75.0)	1 (100)		
Separation of sutures									
Absent	3 (6.0)	0	2 (10.5)	0	0	1 (5.0)	0	1.427	0.921
Present	47(94.0)	1 (100)	17 (89.5)	1 (100)	8 (100)	19 (95.0)	1 (100)		
Engorgement of scalp venous channels									
Absent	36(72.0)	1 (100)	16 (84.2)	0	6 (75.0)	12 (60.0)	1 (100)	6.218	0.286
Present	14(28.0)	0	3 (15.8)	1 (100)	2 (25.0)	8 (40.0)	0		
Dwarfing of the face by a large head									
Absent	36(72.0)	1 (100)	14 (76.7)	0	6 (75.0)	14 (70.0)	1 (100)	3.451	0.631
Present	14(28.0)	0	5 (26.3)	1 (10)	2 (25.0)	6 (30.0)	0		
Sunset appearance of the eyes									
Absent	36(72.0)	1 (100)	15 (79.0)	0	6 (75.0)	13 (65.0)	1 (100)	4.325	0.504
Present	14(28.0)	0	4 (21.0)	1 (100)	2 (25.0)	7 (35.0)	0		
Irritability									
Absent	37(74.0)	1 (100)	16 (84.2)	0	3 (37.5)	17 (85.0)	0	13.870	0.016*
Present	13(26.0)	0	3 (15.8)	1 (100)	5 (62.5)	3 (15.0)	1 (100)		
Vomiting									
Absent	40 (80.0)	1 (100)	15 (79.0)	1 (100)	4 (50.0)	19 (95.0)	0	11.825	0.037*
Present	10(20.0)	0	4 (21.0)	0	4 (50.0)	1 (5.0)	1 (100)		
Poor Sucking									
Absent	43(86.0)	1 (100)	17 (89.5)	0	5 (62.5)	20 (100)	0	19.564	0.002*
Present	7(14.0)	0	2 (10.5)	1 (100)	3 (37.5)	0	1 (100)		
Dull response to the environment									
Absent	44(88.0)	1 (100)	18 (94.7)	0	6 (75.0)	19 (95.0)	0	17.828	0.003*
Present	6(12.0)	0	1 (5.3)	1 (100)	2 (25.0)	1 (5.0)	1 (100)		
Refusal of feeds									
Absent	45(90.0)	1 (100)	16 (84.2)	1 (100)	7 (87.5)	20 (100)	0	12.207	0.032*
Present	5 (10.0)	0	3 (15.8)	0	1 (12.5)	0	1 (100)		
Fever									
Absent	39 (78.0)	1 (100)	15 (79.0	1 (100)	2 (25.0)	20 (100)	0	22.856	<0.001
Present	11 (22.0)	0	4 (21.0)	0	6 (75.0)	0	1 (100)		
Diminished loss of consciousness									
Absent	50 (100)	1 (100)	19 (100)	1 (100)	8 (100)	20 (100)	1 (100)	-	-
Present	-	-	-	-	-	-	-		
Lower and upper extremity weakness									
Absent	47 (94.0)	1 (100)	18 (94.7)	1 (100)	7 (87.5)	20 (100)	0	17.688	0.003*
Present	3 (6.0)	0	1 (5.3)	0	1 (12.5)	0	1 (100)		
Abnormal posturing									
Absent	50 (100)	1 (100)	19 (100)	1 (100)	8 (100)	20 (100)	1 (100)	-	-
Present	-	-	-	-	-	-	-		
Seizures									
Absent	44 (88.0)	1 (100)	16 (84.2)	1 (100)	6 (75.0)	20 (100)	0	11.872	0.037*
Present	6 (12.0)	0	3 (15.8)	0	2 (25.0)	0	1 (100)		
Apnea									
Absent	50 (100)	1 (100)	19 (100)	1 (100)	8 (100)	20 (100)	1 (100)	-	-
Present	-	-	-	-	-	-	-		
Coma									
Absent	50 (100)	1 (100)	19 (100)	1 (100)	8 (100)	20 (100)	1 (100)	-	-
Present		-	–	-	-	-	-		

P-value <0.05 is significant

DISCUSSION

The most common age group in this study is 1-2 (42%) and 3-4 (24%) months. This is similar to the work done by Eze et al where the most common age range was noted to be between 0-5 months.[16] It is also similar to the study done by Nzeh et al which recorded a high age between 0-3 months 76 (77.6%).[17] The reason for this may be early suspicion of intracranial pathology in these patients in hospital-based deliveries as well as prompt referral to the radiology department for transfontanelle ultrasound.[17,18] Another reason for this high number of patients recorded in the early age group may be due to improved obstetrics antenatal care in these hospital based deliveries. The low number of patients noted in the older age group may be due to early surgical intervention. Also, some of these patients may have died at home from neglect as noted by Binitie. [19]

More males (70%) were recorded in this study than females (30%). This is similar to the study done by Saidu et al which recorded 60.9% males and 39.1% females as well as studies done by Bajpai et al and Baruah et al where they all recorded more males than females.[18,20,21] This is different from the study done by Nzeh et al which recorded more females than males.[17] There is no known reason for the male preponderance because the different causes of hydrocephalus has no sex preference.

The most common clinical features in this study are abnormal increase in head circumference (96%), separation of sutures (94%) and tension and bulging of the fontanelles (72%). This is similar to the study done by Ashraf et al which noted a common clinical finding of abnormal increase in head size 80%, splaying of the suture 76% and tense fontanelle 76%.[19] The reason for this is that these are the early presenting features in this condition, therefore they represent the commonest findings in these patients. Other common findings include engorgement of scalp venous channels, dwarfing of the face by a large head, sunset appearance of the eyes, irritability and fever. The least common findings were poor sucking (14%), dull response to the environment (12%), seizures (12%), refusal of feeds 5(10%) and lower and upper extremity weakness (4%). No patient presented with diminished loss of consciousness, abnormal posturing, apnea and coma. This is because these features are seen more in older patients with long standing hydrocephalus.

Hydrocephalus can be congenital or acquired.[22] The congenital causes as shown in this study constitute a major part of the ultrasound findings followed by infective causes which are acquired. The congenital causes include aqueductal stenosis and foramina of Luschka and Magendie obstruction. This is similar to the study done by Saidu et al, Ashraf et al and Nzeh et al which also stated that congenital causes constitute a major part of the findings in patients with hydrocephalus.[18,23,24] The study done by Saidu et al recorded congenital finding of 81%.[18] Improved antenatal scan as well as early presentation to hospital may have contributed to the higher percentage recorded by Saidu et al.[18] This finding contradicts the study done by Tabari et al on 18 infants where he stated that infective causes are commoner than congenital causes.[25] The relatively small sample size may have contributed to this contradiction. Aqueductal stenosis constitutes a major part of the congenital cause, followed by obstruction at the level of foramen of Luschka and Magendie. This is similar to the study done by Saidu et al and Ashraf et al where they noted that aqueductal stenosis was a major finding among the congenital causes.[18,23] The commonest congenital findings in the study done by Saidu et al were cerebral aqueductal stenosis as well as obstruction of the exit foramina of Luschka and Magendie, similar to findings in our study.[18] Nzeh et al also reported foramen of Luschka and Mangendie obstruction and encephalocele as their commonest congenital causes.[24] No encephalocele was seen in this study. Saidu et al reported a low percentage of encephalocele which were associated with

hydrocephalus.[18]

Other ultrasound findings in this study includes masses at the choroid plexus and 4th ventricle which were noted in one patient each with a percentage of 2. The choroid plexus mass was located at the supratentorial region while the 4th ventricular mass was located at the infratentorial region and these are common locations of these masses in this age group. These masses are rare lesions and this reflected in their percentages.

Infective causes like ventriculitis and abscess collection were reported. These are acquired causes which are complications of meningitis and as such do not usually manifest early. Baruah et al and Eze et al in their study on bacterial meningitis documented that infective causes manifest in older age group.[16,21] This explains the reason for the low number of patients with infective conditions in this study.

This study also recorded no obstruction at the level of foramen of Monro unlike the study done by Nzeh et al where one patient was diagnosed with foramen of Monro stenosis.[17] This is usually a rare finding. The study duration and sample size might have contributed to this finding.

No post-haemorrhagic cause of hydrocephalus was recorded in this study. Saidu et al recorded a low incidence.[18] This may be as a result of low incidence of intracranial haemorrhage in our developing countries which is attributed to environmental and genetic factors.[20] Also, lack of well-established pre-term ultrasound screening service in our hospital may have contributed.

Other studies have more findings like cerebral infarcts, dandy walker syndrome, cephaloblastoma, arachnoid cyst and subgaleal cysts.[27,28] These were not seen in our study and the reason may be because the studies with these findings were done over longer duration with larger sample size.

There is no normal finding in this study, which means that the clinical diagnosis is 100% accurate. The study done by Eze et al recorded 47.3% normal findings.[28]

Communicating hydrocephalus was seen in 18% of patients while non-communicating hydrocephalus was seen in 82% patients. The communicating hydrocephalus found in this study are infective conditions like ventriculitis and abscess. The non-communicating hydrocephalus are aqueductal stenosis, obstruction at the level of foramen of Luschka and Magendie, choroid plexus mass and 4th ventricular mass. The reason for the high number of patients with non-communicating hydrocephalus is because congenital anomalies like aqueductal stenosis and obstruction at the level of the foramen of Luschka and Magendie which formed a major part of the non-communicating hydrocephalus are usually diagnosed early. These congenital conditions when detected or suspected during antenatal scanning are then rescanned after delivery and proper diagnosis made immediately after birth. The non-communicating hydrocephalus comprising of infective conditions and haemorrhage are diagnosed at an older age as noted by Baruah et al in their study on acute bacterial meningitis and their sequelae on infants.[21] The finding in this study that non-communicating hydrocephalus has a higher percentage is different from the study done by Eze et al where 77.8% had communicating and 22.2% had non-communicating hydrocephalus.[29]

Their study was done amongst patients with bacterial meningitis. The greater percentage of communicating hydrocephalus noted in their study is because infective conditions are among the major cause of communicating hydrocephalus. Marchie had previously affirmed that ultrasonography to be a very useful modality for investigation of hydrocephalus amongst infants.[30]

This study showed a significant correlation between clinical findings and ultrasound diagnosis with a predictive value of less than 0.05 for irritability, vomiting, poor sucking, dull response to environment, refusal of feeds, fever, lower and upper extremity weakness and seizures. The limitation in this study is the relatively small sample size for which we recommend future studies with large sample size, as well as other

imaging modalities like MRI that will better demonstrate levels of CSF obstruction.

CONCLUSION

There was significant correlation between clinical and radiological diagnosis of hydrocephalus. The most common clinical presentation is abnormal increase in head circumference, separation of sutures and bulging of the fontanelles while aqueductal stenosis, obstruction at the level of foramen of Luschka and Magendie and ventriculitis were the commonest ultrasound findings.

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Author contributions: O.K.C. conceived of the presented idea. O.K.C. and E.U.R. recruited patients, carried out the examination and collected data with the help of U.E.O. and A.C. E.U.R. and O.K.C. wrote the manuscript. E.K.C. and E.J.K.C. supervised the project.

Data availability

The data used to support the findings of this study are available from the site publicly.

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Ethical approval: The study was approved by the Institutional Ethics Committee.

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