ORIGINAL ARTICLE

Reliability of ankle clonus evaluation for monitoring neural-tract integrity in pediatric spinal deformity surgery under different anesthetics protocols

Nusret Ök,[1] Mehmet Yucens,[1] Seda Kıter,[2] Riza Hakan Erbay,[3] Yetkin Söyüncü,[4] Ilker Kiraz,[5] Esat Kiter[6]

[1]Department of Orthopedics, Pamukkale University Medicine Faculty, Denizli-*Türkiye*
[2]Department of Anesthesiology Denizli Government Hospital, Denizli-*Türkiye*
[3]Department of Anesthesiology, Pamukkale University, Denizli-*Türkiye*
[4]Department of Orthopedics, Akdeniz University Medicine Faculty, Antalya-*Türkiye*
[5]Department of Neurosurgery Pamukkale University Medicine Faculty, Denizli-*Türkiye*
[6]Department of Orthopedics, Odak Hospital, Denizli-*Türkiye*

ABSTRACT

BACKGROUND: Although the ankle clonus test is a pathological finding in neurological examination, it may temporarily occur in neurologically intact individuals during awakening from anesthesia. Some studies suggest it as a marker indicating neural tract integrity in pediatric spinal deformity surgery. This study aims to investigate the consistency of the ankle clonus test under different anesthesia protocols in pediatric patients with spinal deformities.

METHODS: A total of 39 patients diagnosed with Adolescent Idiopathic Scoliosis or Scheuermann Kyphosis were enrolled to this prospective study. Patients were divided into three groups based on the anesthesia protocol used. In Group I and Group II, two different anesthetic agents (pentothal vs. propofol) were administered, while Group III received Total Intravenous Anesthesia. All patients underwent surgery with pedicle screw constructs using a standard posterior approach. The presence of clonus was recorded during awakening.

RESULTS: Bilateral ankle clonus was observed in 10 patients (76.9%) in Group I, six patients (46.1%) in Group II, and seven patients (53.8%) in Group III. Clonus was absent in 16 patients (41%) across all groups. There was no significant association between the presence of ankle clonus and factors such as group assignment, duration of surgery, level of instrumentation, or blood loss. No neurological deficits were observed in any patient during the postoperative period.

CONCLUSION: The ankle clonus test is not a reliable method for monitoring neurological deficits during spinal surgery. It is not exactly known how such myoclonic contractions occur or how the pathway is inhibited or activated.

Keywords: Ankle clonus test; pediatric spinal deformity; scoliosis; spinal deformity; wake-up test.

INTRODUCTION

One of the most feared complications of spine surgery is the development of neurological deficits. In deformity surgery, monitoring the neurological pathway before the completion of the surgical procedure is a critical practice that allows for early intervention in the presence of neurological findings. In this regard, the wake-up test, defined in the early 1970s, has

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Address for correspondence: Nusret Ök
Department of Orthopedics, Pamukkale University Medicine Faculty, Denizle, Türkiye
E-mail: oknusret@gmail.com
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been used for a long time to check the integrity of the nerve pathway.[1] Today, neuromonitoring has largely replaced the wake-up test. However, in practice, surgeons may need to rely on traditional methods in cases of technical issues with neuromonitoring or unexpected signal loss.

Ankle clonus is considered a pathological finding within neurological examination. The reflex pathway is not fully understood, and interestingly, ankle clonus can occur temporarily during recovery from anesthesia in neurologically intact patients. A possible cause of temporary clonus during awakening is the reactivation of lower motor neuron functions before cortical inhibitory mechanisms have taken effect. Hoopenfeld et al. were the first to highlight this phenomenon, suggesting that the ankle clonus test during awakening is more reliable than the wake-up test for assessing neural tract integrity.[2] Criticisms of this study largely centered on the concern that "different anesthetic agents might lead to different reflex responses," which led some researchers to question the reliability of the test.[3,4] However, some studies suggest that the test can be used if certain anesthesia-related parameters are controlled.[5,6] Major limitations of previous studies include the use of non-spinal pediatric patients or the absence of control groups. The purpose of the current prospective study is to evaluate the reliability of the temporary ankle clonus test with different anesthetic agents in pediatric deformity cases.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of the Pamukkale University Faculty of Medicine (approval number 2009-64). The study involved a prospective evaluation of 39 patients diagnosed with Adolescent Idiopathic Scoliosis (AIS) or Scheuermann Kyphosis (SK), all requiring surgical treatment and aged between 10 and 20 years. Patients with neuromuscular or syndromic etiologies, a history of previous spinal surgery, cerebral disease, drug allergies, or mental retardation were excluded.

Anesthesia Protocol

Patients were divided into three groups based on the anesthesia protocol. In Group I and Group II, four anesthetic agents were used. In Group I, Pentothal 5-7 mg/kg was administered, while in Group II, Propofol 1.5-3 mg/kg was used for induction. Neuromuscular blockade in these patients was achieved with Vecuronium 0.1-015 mg/kg. Following tracheal intubation, the dose of 1 minimum alveolar concentration (MAC) Desflurane was gradually reached within five minutes. Additionally, Remifentanil infusion at 0.025-0.75 µg/kg/min was started for analgesic support in these patients. In Group III, TIVA (Total Intravenous Anesthesia) was administered, with Propofol at 50-150 µg/kg/min and Remifentanil infusion at 0.025-0.75 µg/kg/min. Approximately one hour before the wake-up test, muscle relaxants were withheld following the surgeon's request.

Surgical Method and Randomization

Patient randomization was conducted according to the surgical appointment order. The TIVA group was added to the study later, once the use of neuromonitoring became routine practice. All patients underwent surgery using pedicle screw constructs with a standard posterior approach. No medullary canal was opened, no osteotomies were performed, and no hooks or sublaminar ligaments were used.

Wake-Up Test and Evaluation of Clonus

The day before surgery, patients scheduled for the wake-up test were informed that they would be awakened during the procedure to check voluntary motor function of the lower limbs. They were reassured that they would not experience any pain, would quickly fall back asleep, and would have no memory of the test. During surgery, once the surgeon requested the wake-up test and anesthesia preparations were completed, the patient was called by their first name and asked to move their hands. After observing hand movement and other signs of awakening, foot movements were observed by knee flexion. The presence of spontaneous clonus, followed by forced clonus, was checked by the same observer in all patients. Following foot movement, the wake-up test was terminated, and the patient was put back to sleep. Absence of any ankle clonus was considered a positive test result.

Statistical Analyses

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 17, 2008, USA). Nominal variables were analyzed with the Chi-Square ($\chi 2$) test and Fisher's Exact Test, while non-parametric variables were analyzed using the Mann-Whitney U and Kruskal-Wallis tests ($p<0.05$).

RESULTS

A total of 39 patients-eight male and 31 female-were included in the study, divided into three groups. There were 13 patients in Group I (11 with AIS and two with SK), 13 in Group II (12 with AIS and one with SK), and 13 in Group III (11 with AIS and two with SK). The mean age of patients was 14.7 (±2.2) years. The mean Body Mass Index was 20.7 (±2.8). The average operation time and blood loss were 308.5 (±102.3) minutes and 1125 (±433.9) cc, respectively. An average of 11.5 (±1.2) vertebral segments were operated on and fixed during surgery. There were no demographic differences between the groups, except for blood loss between Groups II and III (Table 1).

In Group I, the ankle clonus test was positive (no clonus observed) in three patients, in Group II it was positive in seven patients, and in Group III clonus was absent in six patients (Table 1). In other words, clonus occurred in 23 (58.9%) patients across all groups. There was no statistically significant relationship between the positive ankle clonus test and the administered anesthesia protocol (Table 2). No neurological

Table 1. Comparison of variables between groups

Groups	Gender (F/M)	Age (SD)	BMI (SD)	Blood Loss (cc) (SD)	Duration (min) (SD)	Operated Segment
I	11/2	14.3 (2.1)	20.2 (2.1)	1180.7 (315.9)	310 (112.1)	11.8 (0.9)
II	9/4	15.5 (2.3)	21.5 (3)	921.1 (498.3)	278.4 (92.1)	11.2 (1.5)
II	11/2	14.3 (2.1)	20.4 (3.2)	1273 (419.6)	337.3 (101.2)	11.4 (1.33)
Total	31/8	14.7 (2.2)	20.7 (2.8)	1125 (433.9)	308.5 (102.3)	11.5 (1.2)
p[a]		0.266	0.521	0.042	0.460	0.448
p[b]				0.012		

A significant difference was observed in terms of blood loss between Groups II and II. [a]Kruskal-Wallis test (all groups); [b]Mann-Whitney U test (Groups II and III).

Table 2. Positive clonus test results according to anesthesia protocol

	Anesthesia Protocol	Patient (n)	Positive Clonus Test* (%)	Clonus Occurrence	Group II	Group III
Group I	[a]Pentothal-Desflurane	13	3 (23%)	10 (76.9%)	p≥0.113**	p≥0.205**
Group II	[a]Propofol-Desflurane	13	7 (53.8%)	6 (46.1%)	–	p≥0.500**
Group III	[b]Propofol (TIVA)	13	6 (46.1%)	7 (53.8%)	–	
Total		39	16 (41%)	23 (58.9%)		

[a]Vecuronium for neuromuscular blockade, Remifentanil for analgesic support; [b]Remifentanil for analgesic support only; *Absence of clonus; **χ^2 test and Fisher's Exact Test ($p<0.05$).

deficits were observed in any patient during the postoperative period.

DISCUSSION

According to the results of this study, the ankle clonus test was positive in 14 (40%) patients enrolled, meaning that ankle clonus was elicited in 21 (60%) patients during recovery. However, in the study by Hoppenfield et al., which included 1,006 pediatric deformity patients, it was suggested that ankle clonus observed during awakening does not indicate pathology; on the contrary, it is a positive finding indicating medulla spinalis integration. The results of that study showed no false-negative clonus cases, although false-positive clonus was observed in three patients. The authors reported that the sensitivity of the clonus test to assess medulla spinalis integrity in spinal procedures was 100%, with a specificity of 99.7%.[2] In another study conducted on patients undergoing non-spinal surgery, anesthesia with Sevoflurane was evaluated. This study indicated that the ankle clonus test could be used in patients with optimized end-tidal concentration levels.[5] According to Tobias et al., this test can be used to monitor patients with impaired evoked potential during neuromonitoring.[6] However, Ewen et al. conducted a study on pediatric patients undergoing dental surgery and suggested that myoclonic contractions occurring during awakening may vary depending on the anesthetic agents used. They therefore concluded that the test is unreliable due to the potential for different anesthetic agents to affect the presence of clonus.[4] Chang et al. also demonstrated that the use of Propofol significantly inhibits the formation of this reflex in anesthesia for idiopathic scoliosis.[3] A major limitation of Chens's study, however, is the lack of a control group for comparing different agents.

The precise mechanism of ankle clonus is still unknown; however, it is theoretically believed that lower motor neuron functions recover earlier than cortical inhibitory stimuli during awakening. In this process of disinhibition, clonus may occur in the ankle when performing the test.[7] It has been shown that anesthetics agents influence spinal reflexes.[8] In the current study, although not statistically significant, a quantitative reduction in clonus response was noted with the use of Propofol (Table 2). Propofol in particular may more effectively inhibit the appearance of ankle clonus compared to volatile anesthetic agents.[6,9,10]

This study prospectively tested the occurrence of ankle clonus with different anesthesia protocols in pediatric deformity patients. Comparisons between Group I and II allowed for assessment of Pentothal versus Propofol, while Group II and III enabled evaluation of the Propofol-Desflurane and Propofol-Remifentanil combinations. The use of Propofol in both the second and third groups may be considered a limitation of the study. The final group (TIVA) was added to the study following the introduction of routine neuromonitoring in our practice, which has now become standard in many centers. Therefore, we believe this group represents the most realistic scenario in which the wake-up test may be required in con-

temporary pediatric deformity surgery. The small sample size of the groups might be considered another limitation of this study. However, power analysis indicated that eleven patients per group would be sufficient if the anticipated Type I error (false positive) rate is 50%.[3,4] Additionally, the confidence interval suggested by Hoppenfeld is very high (0.003 false positive, 0 false negative), so we believe that the sample size in our study is adequate to test this theory.[2]

In this paper, the absence of ankle clonus was assumed to be a positive test result. This may lead to some confusion. However, the null hypothesis of the study assumes that the presence of clonus is normal. Therefore, a false positive means absence of clonus with no neurological deficit, while a false negative means presence of clonus with a neurological deficit. We consider the blood loss difference between Groups II and III to be negligible, having no major effect on the analysis.

As a result, no significant differences were found between the groups. Given these findings, it is not possible to recommend using clonus presence or absence for standard neurological assessment, as a certain rate of false positivity can be expected in any case.

CONCLUSION

In conclusion, evaluation of ankle clonus is not a reliable method for assessing neural integrity in pediatric deformity surgery. The ankle clonus test is sensitive to the anesthetic agents administered. The exact mechanisms behind these myoclonic contractions, including how the pathway is inhibited or activated, remain unknown. For confirmation of neurological integrity, the Stagnara wake-up test should be used instead of the ankle clonus test.

Ethics Committee Approval: This study was approved by the Pamukkale University Ethics Committee (Date: 30.04.2024, Decision No: 08).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pediatrik spinal deformite cerrahisinde, farklı anestezi protokollerinde ayak bileği klonus testinin nöral trakt bütünlüğünü izlemedeki güvenilirliği

Nusret Ök,[1] Mehmet Yucens,[1] Seda Kıter,[2] Rıza Hakan Erbay,[3] Yetkin Söyüncü,[4] Ilker Kiraz,[5] Esat Kiter[6]

[1]Pamukkale Üniversitesi Tıp Fakültesi, Ortopedi ve Travmatoloji Anabilim Dalı, Denizli, Türkiye
[2]Denizli Devlet Hastanesi, Anesteziyoloji ve Reanimasyon Kliniği, Denizli, Türkiye
[3]Pamukkale Üniversitesi Tıp Fakültesi, Anesteziyoloji ve Reanimasyon Kliniği, Denizli, Türkiye
[4]Akdeniz Üniversitesi Tıp Fakültesi, Ortopedi ve Travmatoloji Anabilim Dalı, Antalya, Türkiye
[5]Pamukkale Üniversitesi Tıp Fakültesi Beyin Cerrahisi Anabilim Dalı, Denizli, Türkiye
[6]Özel Odak Hastanesi, Denizli, Türkiye

AMAÇ: Ayak bileği klonus testi, nörolojik muayenede patolojik bir bulgu olmasına rağmen, anestezi uyanışı sırasında nörolojik olarak sağlam kişilerde geçici olarak ortaya çıkabilir. Pediatrik spinal deformite cerrahisinde bu testin nöral traktın bütünlüğünü gösteren bir işaret olduğunu gösteren yayınlar bulunmaktadır. Bu çalışmanın amacı, pediatrik spinal deformite hastalarında farklı anestezi protokollerinde klonus testinin tutarlılığını araştırmaktır.

GEREÇ VE YÖNTEM: Adölesan idiopatik skolyoz veya Scheuermann kifoz tanısıyla ameliyat edilen toplam 39 hasta prospektif olarak çalışmaya alındı. Hastalar, anestezi protokolüne göre üç gruba ayrıldı. Grup I ve Grup II'de farklı anestezik ajanlar (pentotal ve propofol) kullanıldı, Grup III'te ise total intravenöz anestezi uygulandı. Tüm hastalar pediküler vidalama ile standart posterior yaklaşımla opere edildi. Hastanın anesteziden uyanması sırasında klonus varlığı kaydedildi.

BULGULAR: Grup I'de 10 (%76.9) hastada bilateral ayak bileği klonusu görüldü, Grup II'de 6 (%46.1) hastada, Grup III'te ise 7 (%53.8) hastada ayak bileği klonusu saptandı. Tüm gruplarda toplam 16 (%41) hastada klonus gözlenmedi. Cerrahi süre, enstrümantasyon düzeyi ve kan kaybı gibi değişkenlerle klonus arasında anlamlı bir ilişki bulunmadı. Postoperatif dönemde hiçbir hastada nörolojik defisit saptanmadı.

SONUÇ: Bu çalışma ayak bileği klonus testinin, omurga cerrahisi sırasında gelişebilecek nörolojik defisiti izlemek için istatistiksel olarak güvenilir bir yöntem olmadığını göstermiştir. Bu tür miyoklonik kontraksiyonların nasıl ortaya çıktığı veya yolaklarının nasıl inhibe veya aktive olduğu tam olarak bilinmemektedir

Anahtar sözcükler: Ayak bilek klonus testi; peditrik dedformite; skolyoz; spinal deformite; uyanma testi.

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