ORIGINAL ARTICLE

UDC: 617.581-036.86-07::615.8
DOI: 10.2298/VSP150819056V

Diagnostic accuracy of the A-test and cutoff points for assessing outcomes and planning acute and post-acute rehabilitation of patients surgically treated for hip fractures and osteoarthritis

Dijagnostička tačnost A-testa i tačke preseka za procenu ishoda i planiranje rane i produžene rehabilitacije bolesnika operativno lečenih zbog preloma i osteoartritisa kuka

Aleksandra Vukomanović, Aleksandar Djurović, Zorica Brdareski

Clinic for Physical Medicine, and Rehabilitation, Military Medical Academy, Belgrade, Serbia; Faculty of Medicine of the Military Medical Academy, University of Defence, Belgrade, Serbia

Abstract

Background/Aim. The A-test is used in daily clinical practice for monitoring functional recovery of orthopedic patients during early rehabilitation. The aim of this study was to determine the accuracy of A-test and cutoff point at which the test can separate patients with and without functional disability at the end of early rehabilitation. Also, it was important to determine whether A-test has that discriminative ability (and at which cutoff points) in the first days of early rehabilitation in order to have time to plan post acute rehabilitation. **Methods.** This measurement-focused study was conducted in the Orthopedic Ward during early inpatient rehabilitation (1st−5th day after the operation) of 60 patients with hip osteoarthritis (HO) that underwent arthroplasty and 60 surgically treated patients with hip fracture (HF). For measurements we used the A-test and the University of Iowa Level of Assistance Scale (ILAS) as the gold standard. For statistical analysis we used the receiver operating characteristic (ROC) curve and the area under the curve (AUC) with 95% confidence interval for the results of A-test from the first to the fifth day of rehabilitation, sensitivity, specificity, the rate of false positive and false negative errors, positive and negative predictive value, ratio of positive and negative likelihood ratio, accuracy, point to the ROC curve closest to 0.1 and Youden index for all the cutoff points. **Results.** The AUC was 0.825 (0.744−0.905) for the first day of rehabilitation, 0.922 (0.872−0.972) for the second day of rehabilitation, 0.980 (0.959−1.000) for the third day of rehabilitation, 0.989 (0.973−1.004) for the fourth day, and 0.999 (0.996−1.001) for the fifth day of rehabilitation. The optimal cutoff for the results of A-test was: 7/8 for the first day, 29/30 for the fourth day, and 34/35 for the fifth day of rehabilitation. On the second and the third day A-test had two cutoff points, the lower point safely separated the patients with functional disability, while the upper point ruled out functional disability. On the 2nd rehabilitation day the cutoff points were 12/13 and 17/18, on the 3rd rehabilitation day cutoff points were 13/14 and 18/19. **Conclusion.** The A-test has all characteristics of an accurate tool which can be used for separating patients with and without functional disability at all stages of early rehabilitation after surgically treated hip disease or fracture. Based on the results of A-test within the first days of early rehabilitation, it is possible to make a plan for postacute rehabilitation.

Key words:
rehabilitation; recovery of function; hip prosthesis; postoperative period; predictive value of tests; serbia.

Apstrakt

Uvod/Cilj. A-test se koristi u svakodnevnoj kliničkoj praksi za praćenje ortopedskih bolesnika tokom rane rehabilitacije. Cilj ove studije bio je da se utvrdi tačnosti A-testa i odrede tačke preseka na kojima A-test odvaja bolesnike od onih bez funkcionalne nesposobnosti na kraju rane rehabilitacije. Takođe, da bi se napravio plan produžene rehabilitacije, cilj nam je bio da utvrdimo da li A-test ima tu diskriminatornu sposobnost (i na kojim tačkama preseka) i tokom prvih dana rane rehabilitacije. **Metode.** Ova studija usmerena na ispitivanje mernog instrumenta sprovedena je na Ortopedskom odeljenju tokom râne rehabilitacije (1–5. postoperativni dan) na 60 bolesnika nakon artroplastike kuka zbog osteoartritisa i 60 bolesnika nakon operativno lečenog preloma kuka. Za merenja smo koristili A-test i the *University of Iowa Level of Assistance Scale* (ILAS) kao zlatni standard. Statistička analiza obuhvatala je ROC krivu i površinu ispod krive (AUC) sa 95% intervalom pouzdanosti za rezultate A-testa od 1. do 5. dana rehabilitacije senzitivnost, specifičnost, stopu lažno pozitiv-

Correspondence to: Aleksandra Vukomanović, Clinic for Physical Medicine and Rehabilitation, Military Medical Academy, Crnotravska 17, 11 000 Belgrade, Serbia. Phone: +381 64 197 2754. E-mail: aleksandravukomanovic@yahoo.com

ne i lažno negativne greške, pozitivnu i negativnu prediktivnu vrednost, odnos pozitivnog i negativnog odnosa verovatnoće, tačnost, tačku na ROC krivi najbližu (0.1) i Youden index za sve tačke preseka. **Rezultati.** Vrednosti AUC iznosile su: 0,825 (0,744−0,905) za 1. dan rehabilitacije, 0,922 (0,872−0,972) za 2. dan, 0,980 (0,959−1,000) za 3. dan, 0,989 (0,973−1,004) za 4. dan i 0,999 (0,996−1,001) za 5. dan rehabilitacije. Optimalna tačka preseka za rezultate A-testa bila je: 7/8 za 1. dan, 29/30 za 4. dan i 34/35 za 5. dan rehabilitacije. Drugog i 3. dana rehabilitacije A-test imao je dve tačke preseka, a nižom tačkom se pouzdano odvajaju bolesnici sa funkcionalnom nesposobnošću, dok se višom tačkom odbacuje postojanje funkcionalne nesposobnosti. Drugog dana rehabilitacije tačke preseka bile su 12/13 i 17/18, a 3. dana 13/14 i 18/19. **Zaključak.** A-test ima karakteristike dijagnostički tačnog testa koji može da odvoji bolesnike sa i bez funkcionalne nesposobnosti u svim fazama rane rehabilitacije bolesnika koji su operativno lečeni zbog oboljenja ili preloma kuka. Na osnovu rezultata A-testa tokom prvih dana rane rehabilitacije moguće je napraviti plan za produženu rehabilitaciju.

Ključne reči:
rehabilitacija; funkcija, povratak; kuk, proteza; postoperativni period; testovi, prognostička vrednost; srbija.

Introduction

Due to injuries or planned surgery, all patients admitted to the Clinic for Orthopedic Surgery and Traumatology (COST) experience a lower or higher degree of functional disability. Surgical treatment allows early mobilization of patients. The goals of early initiation of rehabilitation are to maintain or reduce the loss of functioning and to accelerate recovery and patients early autonomy [1]. The ultimate goal is to prevent disability and to avoid the need for long-term care [1]. For most patients, changes in functional status occur from day to day. From the condition of functional disability, some patients come to the state of greater or lesser functional independency for several days. Some of patients progress slowly, so they more or less dependend on the therapist's help in performing basic activities at discharge. Our rehabilitation team at the COST is a witness of these changes. But in routine work we have a problem to record the changes that occur from day to day in a simple and easy way. As in all other areas of physical medicine and rehabilitation, assessing and measuring outcomes are essential in early rehabilitation. Assessment is important for four reasons: decision on further treatment of patients, monitoring and verification of the process of rehabilitation, clinical research and better planning of health services [2]. However, it seems that it is still not easy to find or develop a suitable measure for functioning [3].

Following the early rehabilitation program, we created the A-test to assess 10 basic activities a patient needs to regain in this period. For each activity, the patient receives a score from 0 to 5 depending on the degree of autonomy. The tenth item of the test is walking endurance, and it is graded from 0 to 5 according to the distance that the patient is able to cross. Total scores can range from 0 to 50, or from inability to perform any activity with the help of the therapists to complete independence and safety in performing all activities (Appendix 1). The test was called the A-test (A−for assessment or activity).

First, we used the A-test in a study to assess the effects of preoperative physical therapy and education of patients scheduled for hip arthroplasty [4]. Then we continued to use A-test in everyday practice to make it easier to monitor the process of rehabilitation of each patient from day to day. The A-test is not an additional obligation to the therapists because each activity in the test is an integral part of early rehabilitation program and has been practiced in the COST for years. After the session, the therapists recorded the degree of independency which each patient achieved for a particular activity from the early rehabilitation program. It takes less than 1 minute to the physiotherapist to complete A-test form for each patient. Also, we find that A-test is valid and reliable measurement tool for assessment of functional recovery during early rehabilitation of patients in the Orthopedic Ward [5, 6].

We believe that A-test could help us in making decisions about further treatment and planning health services. The pressure to shorten the stay in the surgical units is ubiquitous, and we are not an exception to this phenomenon. On the other hand, the problem is the small capacity of the rehabilitation department. Candidates for transfer to the rehabilitation department are patients who, until discharge from the COST, did not achieve a satisfactory degree of independence in basic activities. The importance of A-test in this case would be to separate these patients from the group of patients who achieved a satisfactory degree of independence and can be discharged home to continue rehabilitation. So, the aim of this study was to determine which is the most appropriate cutoff for separating these two groups of patients. There was another clinical dilemma, however, thas we expect the A-test to help us in solving it. We usually discharged patients from the COST on the seventh day of the operation. The plan for transfer should be made several days earlier. In the first days after the surgery the A-test score is much lower for most patients, and in that case the cutoff should also be set lower than on discharge, because we would, otherwise, transfer almost all patients from the COST to the rehabilitation department. Therefore the aim of this study was also to determine the cutoff point for solving the transfer plan in the first days after surgery. In addition to determining the cutoff points of A-test during early rehabilitation, the aim of this study was to evaluate the A-test in terms of other features of test accuracy, as well.

Methods

This prospective study was conducted in the COST of Military Medical Academy, Belgrade, on 120 patients of both sexes: 60 patients with acute hip fracture and 60 pati-

ents who underwent hip arthroplasty due to osteoarthritis. Patients with hip fracture were able to walk or without aids and up-and down stairs (help of another person was allowed for this activity) before the injury. This study did not include patients with dementia, pathological hip fractures, bilateral hip fractures, concurrent fracture in any other part of the body, and patients to whom surgical treatment is contraindicated. Patients who underwent hip arthroplasty due osteoarthritis were, also, without significant mental disability, and were able to walk with or wihout aids, and up- and downstairs (help of another person was allowed for this activity) before the operation.

Exclusion criteria during the study were the occurrence of intraoperative or postoperative complications that prevented or delayed the start of rehabilitation, lethal outcome immediately after surgery and incomplete collected data for individual patient.

All the patients were treated surgically. The modality of treatment depended on the type of fracture: osteosynthesis with a dynamic hip screw was applied to patients with intertrochanteric fracture, and arthroplasty was performed in patients with fractures of the femoral neck (partial arthroplasty for older than 70 and total arthroplasty for younger than 70). All the patients admitted with arthritis of the hip were underwent arthroplasty.

After the surgery, all the patients had the same rehabilitation treatment, which involved early mobilization of the patient at the bedside (from the first postoperative day, unless the general condition of the patient did not allow), progressive verticalization (in accordance with the possibilities of the patient), walking with aids on the flat as well as up- and downstairs, practicing the basic activities of daily living (using the toilet, sitting down in a chair). Daily physical therapy treatment lasted 30 minutes, and it was applied every working day (from Monday to Friday). The allowable weight bearing when walking depended on the modality of surgery.

Data on comorbidity and the used drugs, mental and functional status before injury (for the patients with hip fracture) and on admission (for the patients with hip osteoarthritis) (walking distance, the ability to walk up- and downstairs, use of walking aids, carrying out basic and instrumental activities), as well as socio- epidemiological data (marital status, housing conditions) were collected from all the patients on admission. Assessment of the mental status was made using the Serbian version of the shortened mental test score [7], while the functional status before injury was assessed by the New Mobility Score [8].

In the postoperative period, from the first day of rehabilitation until discharge, each patient's functional status was assessed by using the A-test and The University of Iowa Level of Assistance Scale (ILAS) [9, 10].

By the protocol, postoperative complications that occurred and slowed down the course of rehabilitation, the number of days of treatment, duration of hospitalization after the surgery, and destination after discharge were recorded.

We conducted this research with the approval of the competent local Ethics committee.

The diagnostic test accuracy and the best position of the cutoff point were determined using the receiver operating characteristic (ROC) curve [11–13]. The ROC curve was determined for the first five days of rehabilitation in the SSPS 10.0 program. Based on the score of ILAS on the fifth day of rehabilitation (the seventh day after the surgery) the patients were divided into two groups: patients with a score above 10 were considered to require inpatient rehabilitation, while patients with a score of 10 and less could continue rehabilitation at home.

The fifth day of rehabilitation (the seventh day after surgery) was chosen because hospital stay after the surgery took usually 7 days. The cutoff point for ILAS was arbitrarily defined and we were guided by the following principles: the patient is supposed to get out of bed and walk independently or under supervision of the therapist, but without support (maximum 3 points for these 3 activities), holding by the therapist was allowed while walking up- and downstairs if the patient performed this activity before admission to the hospital with the help of another person (maximum 2 points), and the patient should cross the length of 13.4 m for no more than 70 seconds (maximally 5 points).

The diagnostic accuracy of the A-test was estimated by the value of the area under the curve (AUC). The AUC greater than 0.9 was considered the distinction of high accuracy, while 0.7−0.9 indicated moderate accuracy and the values of 0.5 to 0.7 were associated with low accuracy [14]. Standard error, significance level and 95% confidence intervals were presented with the value of the AUC.

For each cutoff point the following parameters were calculated by using standard statistical procedures: sensitivity, specificity, false positive error rate, the rate of false negative errors, positive and negative predictive values.

Also, for each cutoff point we calculated the positive likelihood ratio (LR+), as the ratio of sensitivity and false positive error rate, negative likelihood ratio (LR-), as the ratio of false negative errors and specificity, and the ratio LR+/ LR-. The ratio of LR+ and LR- which was about 50, we considered the feature of precise test [15].

The accuracy of the test was calculated as a proportion of all patients who were correctly diagnosed by this test: (true positives + true negatives)/ total number of examined patients [16].

To determine the optimal cutoff point, we used two previously described methods: point on the ROC curve closest to 0.1 and the Youden index(j) [11, 12].

The first method assumes that the best cutoff point for balancing the sensitivity and specificity of the test is the point on the curve closest to the 0.1 point. In this method, optimal sensitivity and specificity are defined as those yielding the minimal value for $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$. The cutoff point corresponding to these sensitivity and specificity values is the one closest to the 0.1 point and is taken to be the cutoff point that best differentiates between people with disease and those without disease [11].

The Youden index is defined as the maximum vertical distance between the ROC curve and the diagonal or chance line and is calculated as J = maximum {sensitivity + specificity −1}. Using this measure, the cutoff point in the ROC curve which corresponds to J, that is, at which (sensitivity + specificity − 1) is maximized is taken to be the optimal cutoff point [11].

Results

Out of the 120 patients included in the study, 15 patients (10 with hip fracture and 5 with osteoarthritis of the hip) were excluded during the study: 2 patients with intertrochanteric fracture were excluded due to poor operative stabilization of the fracture and orthopedic surgeon recommendations to rest after surgery, 2 patients with hip fracture were excluded due to cardiac disorders and recommendations of cardiologists to delay mobilization, 3 patients (2 with hip fracture and one with osteoarthritis) were excluded because of the debilitating diarrhea, severe electrolyte imbalances and extreme hypotension so physiatrist recommended postponing initiation of early rehabilitation, in 1 patient with hip fracture and with symptoms of pulmonary embolism, early rehabilitation was interrupted in the first days after the surgery as recommended by the pulmonologists, 4 patients died in the first days after surgery (3 patients with hip fracture and one with osteoarthritis of the hip), 3 patients with osteoarthritis had no completely collected data (hospital discharge was performed before the seventh day after surgery).

Complications that occurred in other patients, because of which we did not delay the start of early rehabilitation were: confusion, gastric complaints, hypotension, urinary tract infection, short-term diarrhea, the occurrence of pressure ulcers in the sacral region and on the feet, vomiting.

Demographic characteristics, numbers of concomitant diseases and used medications, mental and functional state, socioepidemiological data, hospital stay and rehabilitation duration are shown in Table 1. The patients with hip fracture had occasional mild mental problems before the injury, mainly related to the recall of new information, while patients scheduled for arthroplasty had perfectly satisfactory mental state. It can be observed from the data that the patients with hip fracture had plenty of good mobility before the injury. In the group of patients with hip fracture there was a greater proportion of people whose spouse died and who lived alone. After discharge home, a large percentage of patients (33% in the group with osteoarthritis and 28% in the hip fracture) encountered an obstacle, because they lived in an apartment without the elevator.

The distribution of the values of A-test results for all patients who were followed from the first to the fifth day is given in Figure 1. From the first to the fifth day of rehabilita-

Table 1

Demographic characteristics, comorbidity, mental and functional status before admission/injury, socioepidemiological data, hospital stay and rehabilitation duration

Patients' characteristics	The group of patients with osteoarthritis of hip (n = 55)	The group of patients with hip fracture (n = 50)	*p*
Age (years)[1]	65 ± 12; 53 (32–85)	75 ± 10; 76 (47–89)	0.000*
female[2]	32 (58)	37 (74)	0.088†
Number of comorbid diseases[1]	1 ± 1; 1 (0–4)	2 ± 1; 2 (0–4)	0.005*
Number of used drugs[1]	2 ± 2; 2 (0–8)	3 ± 2; 3 (0–9)	0.083*
Shortened mental test score (Serbian version) [1]	10 ± 0; 10 (10–10)	9.84 ± 0.51; 10 (8–10)	0.017‡
Occasional confusion[2]	0 (0%)	3 (6%)	
New Mobility Score[1]	7 ± 2; 6 (2–9)	7 ± 2; 9 (1–9)	0.009‡
Limited walking distance[2]	41 (74.5)	26 (52)	0.016†
Aids when walking[2]	28 (51)	16 (32)	0.050†
Up and down stairs with difficulty[2]	51 (93)	32 (64)	0.000†
Lives in the flat without elevator[2]	18 (33)	14 (28)	
Lives alone[2]	7 (13)	10 (20)	
A widow / widower[2]	14 (26)	23 (46)	
Hospital stay (day)[1]	7.44 ± 1.08, 7 (7–12)	8.52 ± 3.40, 7 (7–24)	0.035*
Rehabilitation (day)[1]	5.25 ± 0.78, 5 (5–10)	6.20 ± 2.28, 5 (5–16)	0.007*
5 days of rehabilitation[2]	46 (84)	33 (66)	

[1]x̄ ± SD, median (range); [2]n (%); **t*-test; †Pearson χ^2; ‡Mann Whitney test.

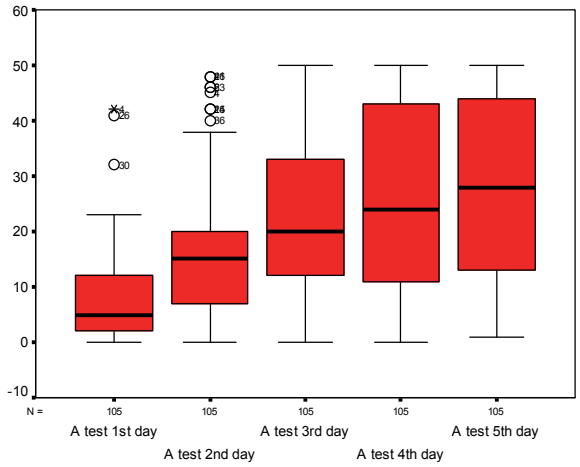

Fig. 1 – Distribution of A- test scores from the first to the fifth day of rehabilitation.

tion pronounced dispersion parameters were found. The parameters of central tendency and dispersion [mean ± SD, mediana range (minimum-maximum)] for the first day of rehabilitation were: 8 ± 8; 5; (0–42), for the second day of rehabilitation: 16 ± 12; 15; (0–48), for the third day of rehabilitation: 22 ± 14; 20; (0–50), for the fourth day of rehabilitation: 26 ± 16; 24; (0–50) and for the fifth day of rehabilitation: 28 ± 16; 28; (1–50).

Based on the ILAS score on the fifth day of rehabilitation, all the patients were divided into two groups: 46 patients with the score of ILAS smaller or equal to 10 were classified in the group without functional disability (37 patients after hip arthroplasty due to hip osteoarthritis, and 9 patients after surgically treated hip fracture), while 59 patients with the score of ILAS greater than 10 were classified in the group with functional disability (18 patients after hip arthroplasty due to hip osteoarthritis, and 41 patients after surgically treated hip fracture).

In Figure 2, ROC curves were plotted from the first to the fifth day of rehabilitation. Day after day, the ROC curve approached the upper left corner of the diagram. On the fifth day of rehabilitation the ROC curve almost reached the upper left corner, which was one of the features of high accuracy of the test.

The AUC indicated a high-accuracy of A-test from the second to the fifth day of rehabilitation (Table 2). Only on the first day of rehabilitation the AUC was slightly smaller, indicating moderate accuracy.

For the first day of rehabilitation, all parameters that determined the optimal cutoff point indicated that it was 7/8. The highest values of LR+/LR-, accuracy and the Youden's index, and the minimum value of point of ROC curve closest to (0.1) are related to this point (Table 3).

On the second day of rehabilitation the lower cutoff po-

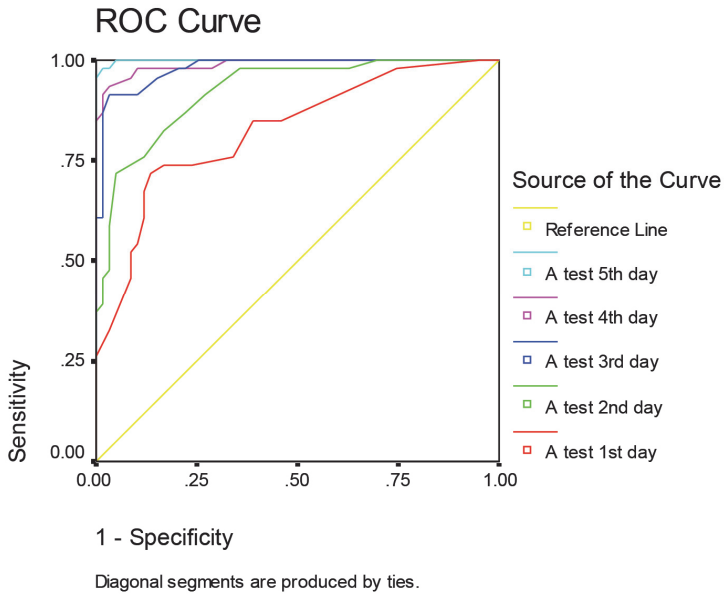

Fig. 2 – The receiver operating characteristic (ROC) curve for A-test from the first to the fifth day of rehabilitation.

Table 2

The area under the curve (AUC): A-test form the first to the fifth day

Postoperative days	Area	Std. error	Asymptotic sig.	Asymptotic 95% CI	
				lower bound	upper bound
1st	0.825	0.041	0.000	0.744	0.905
2nd	0.922	0.025	0.000	0.872	0.972
3rd	0.980	0.010	0.000	0.959	1.000
4th	0.989	0.008	0.000	0.973	1.004
5th	0.999	0.001	0.000	0.996	1.001

Table 3

A-test – cutoff points for the first day of early rehabilitation and related sensitivity, false positive rate of error (1-specificity), positive and negative predictive value, positive and negative likelihood ratio, the ratio of positive and negative, accuracy, minimum 0.1 point and the Youden's index

Cutoff	Sensitivity	1-specificity	PPV	NPV	LR+	LR-	LR+/LR-	Accuracy	Min 0.1 point	Youden index
5/6	0.76	0.26	0.79	0.71	3.22	0.35	9	0.75	0.12	0.50
6/7	0.83	0.26	0.80	0.77	4.92	0.35	14	0.79	0.10§	0.57
7/8*	0.86	0.28	0.80	0.80	6.35	0.39	16†	0.80‡	0.10§	0.58‖
8/9	0.88	0.33	0.78	0.82	7.40	0.48	15	0.79	0.12	0.56

***Selected cutoff point; †maximal LR+/LR-; ‡maximal accuracy; §minimal value of point of receiver operating characteristic (ROC) curve closest to (0.1); ‖maximal Youden's index; PPV – positive predictive value; NPV – negative predictive value; LR+ – positive likelihood ratio; LR- – negative likelihood ratio.**

int was 12/13 and the upper point 17/18. LR +/LR-ratio indicated lower point, while the accuracy and the Youden index indicated upper point (Table 4).

On the third day of rehabilitation the situation was similar, only, the cutoff points were slightly higher. The lower cutoff, indicating the slow progress in functional recovery of the patient, was 13/14. The upper cutoff, which we could use to reject a problem in functional improvement, was 18/19 (Table 5).

On the fourth rehabilitation day, parameters that defined the optimal cutoff point indicated that it could be 29/30 (Table 6). The highest values of LR+/LR-, accuracy and Youden's index, and the minimum value of the point of ROC curve closest to 0.1 were related to this point (Table 6).

On the fifth day of rehabilitation, optimal cutoff could be 34/35. The greatest value of LR+/LR-, accuracy and Youden's index, and the minimum value point of the ROC curve closest to 0.1 were related to this point (Table 7).

Table 4

A-test – the second day of early rehabilitation: cutoff points and related parameters

Cutoff	Sensitivity	1-specificity	PPV	NPV	LR+	LR-	LR+/LR-	Accuracy	Min 0.1 point	Youden index
11/12	0.63	0.02	0.97	0.67	1.68	0.02	75	0.78	0.14	0.61
12/13*	0.64	0.02	0.97	0.68	1.81	0.02	80†	0.79	0.13	0.62
13/14	0.73	0.09	0.91	0.72	2.69	0.10	28	0.81	0.08	0.64
14/15	0.78	0.13	0.89	0.76	3.55	0.15	24	0.82	0.07	0.65
15/16	0.83	0.17	0.86	0.79	4.92	0.21	23	0.83	0.06§	0.66
16/17	0.88	0.24	0.83	0.83	7.40	0.31	24	0.83	0.07	0.64
17/18*	0.95	0.28	0.81	0.92	18.61	0.39	47	0.85‡	0.08	0.67‖
18/19	0.97	0.41	0.75	0.93	28.41	0.70	40	0.80	0.17	0.55

***Selected cutoff point; †maximal LR+/LR-; ‡maximal accuracy; §minimal value of the point of the receiver operating characteristic (ROC) curve closest to (0.1); ‖maximal Youden's index; PPV − positive predictive value; NPV − negative predictive value; LR+ − positive likelihood ratio; LR- − negative likelihood ratio.**

Table 5

A-test – the third day of early rehabilitation: cutoff points and related parameters

Cutoff	Sensitivity	1-specificity	PPV	NPV	LR+	LR-	LR+/LR-	Accuracy	Min 0.1 point	Youden index
12/13	0.63	0.02	0.97	0.67	1.68	0.02	75	0.78	0.14	0.61
13/14*	0.64	0.02	0.97	0.68	1.81	0.02	80†	0.79	0.13	0.62
14/15	0.73	0.09	0.91	0.72	2.69	0.10	28	0.81	0.08	0.64
15/16	0.78	0.13	0.89	0.76	3.55	0.15	24	0.82	0.07	0.65
16/17	0.83	0.17	0.86	0.79	4.92	0.21	23	0.83	0.06§	0.66
17/18	0.88	0.24	0.83	0.83	7.40	0.31	24	0.83	0.07	0.64
18/19*	0.95	0.28	0.81	0.92	18.61	0.39	47	0.85‡	0.08	0.67‖
19/20	0.97	0.41	0.75	0.93	28.41	0.70	40	0.80	0.17	0.55

***Selected cutoff point; †maximal LR+/LR-; ‡maximal accuracy; §minimal value of the point of the receiver operating characteristic (ROC) curve closest to (0.1); ‖maximal Youden's index; PPV − positive predictive value; NPV − negative predictive value; LR+ − positive likelihood ratio; LR- − negative likelihood ratio.**

Table 6

A-test – the fourth day of early rehabilitation: cutoff points and related parameters

Cutoff	Sensitivity	1-specificity	PPV	NPV	LR+	LR-	LR+/LR-	Accuracy	Min 0.1 point	Youden index
24/25	0.90	0.02	0.98	0.88	8.80	0.02	391	0.93	0.01§	0.88
25/26	0.92	0.04	0.96	0.90	10.76	0.04	240	0.93	0.01§	0.87
27/28	0.97	0.07	0.95	0.96	28.41	0.07	409	0.95‡	0.01§	0.90‖
29/30*	0.98	0.09	0.94	0.98	57.82	0.10	607†	0.95‡	0.01§	0.90‖
30/31	0.98	0.11	0.92	0.98	57.82	0.12	473	0.94	0.01	0.87

***Selected cutoff point; †maximal LR + / LR-; ‡maximal accuracy; §minimal value of point of receiver operating characteristic (ROC) curve closest to (0.1); ‖maximal Youden's index; PPV − positive predictive value; NPV − negative predictive value; LR+ − positive likelihood ratio; LR- − negative likelihood ratio.**

Table 7

A-test – the fifth day of early rehabilitation: cutoff points and related parameters

Cutoff	Sensitivity	1-specificity	PPV	NPV	LR+	LR-	LR+/LR-	Accuracy	Min 0.1 point	Youden index
29/30	0.95	0.00	1.00	0.94	18.61	0.00	-	0.97	0.00§	0.95
31/32	0.97	0.02	0.98	0.96	28.41	0.02	1263	0.97	0.00§	0.94
34/35*	0.98	0.02	0.98	0.98	57.82	0.02	2571†	0.98‡	0.00§	0.96‖
36/37	1.00	0.04	0.97	1.00	-	0.04	-	0.98‡	0.00§	0.96‖

***Selected cutoff point; †maximal LR+/LR-; ‡maximal accuracy; §minimal value of point of receiver operating characteristic (ROC) curve closest to (0.1); ‖maximal Youden's index; PPV − positive predictive value; NPV − negative predictive value; LR+ − positive likelihood ratio; LR- − negative likelihood ratio.**

Discussion

This study investigated diagnostic accuracy of the A-test in the assessment of functional recovery of patients treated surgically due to hip fracture and osteoarthritis in the Orthopedic Ward. We determined cutoff points to separate patients with from those without disabilities from the beginning to the end of early rehabilitation. Early rehabilitation of these patients is a dynamic process of short duration. Changes in functional status occur from day to day and their recording is essential for monitoring the recovery of patients, but also for planning their further rehabilitation.

The population of patients admitted to the COST was heterogeneous. However, two clinical entities were the most numerous: fractures of the hip and hip osteoarthritis. Therefore, our study included patients with these admission diagnoses. The patients with hip osteoarthritis who were scheduled for arthroplasty usually recover quickly after surgery. On the other hand, the patients with hip fractures often have a delayed recovery and occurrence of complications changes the flow of rehabilitation. But in both groups of patients, there were those who would deviate from the expected pace of recovery.

It can been seen in the chapter on the results that all parameters that determined the optimal cutoff point indicated that it was 7/8 for the first day of rehabilitation. In practice this means that patients who get out of bed on the first day with the help of the therapists, walk around the room and out into the hallway (A-test score of 8 and higher) will not easily fall into the group of patients with functional disability as the rate of false-negative error is quite low (0.14). The negative predictive value is quite high (0.80), which could mean that 80% of these patients will have no need for inpatient rehabilitation after the fifth day of rehabilitation. However, the LR+/LR- is quite low, the maximum value is 16. Also, it should be noted that the AUC is 0.825, and on the next day the area is higher. Therefore, we recommend that special attention should be paid to all patients with the A-test score less than 8 on the first day of rehabilitation, and that the final decision on further rehabilitation should be left for the next day. A study of Hulsbæk et al. [17], also shows that patients undergoing hip fracture surgery, who are not able to complete physiotherapy on the first post-operative day, are at a greater risk of not regaining basic mobility during hospitalization.

The results obtained for the second and the third day after rehabilitation were interesting for interpretation. The AUC indicate a high accuracy for both test days. This would mean that as early as then we could make a plan for the transfer of patients to the rehabilitation unit based on the score of A-test. And it is very important from the clinical point of view. However, when you look at other parameters that determine the best cutoff point and confirm the accuracy of the test it is easy to notice a discrepancy. We therefore consider that for these two days, in fact, there were two cutoff points for each curve: upper to rule out functional disability with high probability and lower to rule in functional disability with high probability [15].

As noted above, on the second day of rehabilitation the lower cutoff point was 12/13 and the upper point was 17/18. From the clinical point of view this would mean that we would not be (much) wrong if we planned patients with A-test score of less than 13 for the transfer as the rate of false positive error is minimum 0.02. Also, it would be not a (big) mistake to predict that patients with the score of 18 and more will become independent until the fifth day of rehabilitation, as the rate of false negative errors is small 0.05 and negative predictive value is great 0.92. The patients who had the A-test score from 13 to 17 on the second day of rehabilitation should be followed in the coming days. The probability to make the mistake is higher as the rate of false positive and false negative error is higher.

On the fourth rehabilitation day, parameters that define the optimal cutoff point indicated that it could be 29/30. This means that patients whose A-test scores are 30 and higher can be discharged home after five days of rehabilitation, because most activities are performed independently, and the importance of the therapist's presence is limited to verbal suggestion. The rate of false-negative error related to this cutoff point is small (only 0.02). In this study this is one patient. By analyzing the results of A-test in the patients we found that the patient performed all activities quite independently, except walking up- and downstairs. The patient even refused to attempt this activity because it was irrelevant to her everyday life (she lived in the apartment with the elevator). Therefore, her A-score test was greater than 30, and the score of ILAS-a greater than 10. Patients with A-test score of 29 or less require inpatient rehabilitation longer than 5 days in 94% of cases, which indicates a positive predictive

value. The rate of false positive error was 0.09, which ment that rehabilitation facilities would be burdened with 4 patients who could have been discharged home.

On the fifth day of rehabilitation, the optimal cutoff could be 34/35 and that is acceptable from the clinical aspect. But if we want to avoid a false positive error, the cutoff could be 29/30. However, the optimal cutoff point 34/35 is characterized by the following features: high sensitivity, which means that, with the help of A-test, we can detect the existence of functional dependence in performing basic activities when it actually exists in 98% of cases, a low rate of false negative errors (in 2% of cases, this test fails to detect the existence of a functional dependency), high specificity, which shows that in 98% of cases, the A-test show that there is no functional dependence when it is really so, and low rate of false positive errors which shows us that the A-test fails to diagnose the functional dependence when it is present in only 2% of cases. The positive predictive value is very high on this cutoff point, which means that 98% of respondents with positive result are truly functionally dependent. The negative predictive value was also high, revealing that 98% of respondents with a negative result had no significant functional disability.

Measurements of mobility on the second day after the surgery are significant and reliable predictors of independence on transfers and ambulation [18]. In patients with hip fractures, The Cumulated Ambulantion Score of 10 and more for the first three days after the surgery, predicts whether a patient will be discharged home within 2 weeks in 76% of cases [19]. Our clinical experience suggests that a patient who gets out of bed, leaves the room and walkes in the hall department on the first day of rehabilitation with the help of a therapist has a great opportunity to be found in the group of patients who after the fifth day of rehabilitation can be discharged home. In this analysis, the "optimal" cutoff points are presented. A patient who has A-test score 8 and more on the first day, 18 and more on the second day, 30 or more on the fourth day of rehabilitation has a good pace of recovery and will be found in the group of patients who can be discharged home on the fifth day (score 35 and more).

Now we know that we will pay special attention to patients who achieve a score of less than 8 on the first day of rehabilitation. If they do not make a significant functional improvement on the second day of rehabilitation (their A-test score is less than 13), as early as then we can plan them for continuing inpatient rehabilitation.

By monitoring the patients from day to day, we can easily notice stagnation in the functional recovery and immediately take some of the available measures. Let's say that a patient achieved A-test score 12 on the first rehabilitation day, but the score remained the same on the second day of rehabilitation. If this stagnation is not associated with the appearance of some of the complications, the first measure would be to intensify physical therapy. Intensive physical therapy during this period will accelerate functional recovery [20–22] and reduce hospital stay [23]. We do not have the capacity to implement physical therapy in two or more terms for all patients, but adding the term target for patients with delayed recovery can always be arranged. Based on the A-test score, we can specifically and accurately plan additional physical therapy for patients who really need it. It would certainly be a contribution to a better use of health resources.

Based on the analysis we obtained the value of the cutoff point that will be the criterion for further in-patient rehabilitation. The patients with a score of less than 35 on the fifth day of rehabilitation should move to the rehabilitation unit because they need help of a physiotherapist when performing certain activities, while patients with a score of 35 and higher can be discharged home because they can perform most activities independently, a therapist help is limited to verbal suggestion.

The ROC curve is a useful method for assessing responsiveness [24]. It provides a very useful overview of the relationship between a measure and an external indicator of change [24]. The appearance of ROC curves and almost maximum AUC of the fifth day of rehabilitation call attention. Obviously, the ILAS and A-test almost identically assess patient's functional ability/disability. Although the ILAS estimates a smaller number of functions, A-test is much more convenient for everyday work. And from this analysis we see how important it is to assess the outcome of each day, not only at the end of early rehabilitation.

In the presented study, we were concentrated on patients with hip fractures and osteoarthritis who were treated surgically in the COST. From our experience, we expected to find a proportional number of patients in our sample to be discharged home and those who should continue in-patient rehabilitation, which was essential for statistical analysis. Testing should be extended to patients with injuries and disease of other segments of the lower extremities and check the diagnostic accuracy of the A-test in these situations.

Regardless the number of premorbid predictive factors to be taken into consideration when predicting the recovery of the patient [25], early rehabilitation outcome is often unpredictable. Therefore, we emphasize that daily monitoring of functional recovery after the surgery is very important. And if an instrument should be used in clinical practice it has to be simple and should not further burden personnel or patients. Also, an instrument like that has a greater potential to be applied in randomized studies [26].

Conclusion

The A-test has characteristics of an accurate tool for separating patients with from those without functional disability at all stages of early rehabilitation after surgically treated hip disease or fracture. Based on the results of A-test in the first days of early rehabilitation it is possible to make a plan for postacute rehabilitation.

REFERENCES

1. *Stucki G, Stier-Jarmer M, Grill E, Melvin J.* Rationale and principles of early rehabilitation care after an acute injury or illness. Disabil Rehabil 2005; 27(7−8): 353−9.
2. *Küçükdeveci AA, Tennant A, Grimby G, Franchignoni F.* Strategies for assessment and outcome measurement in physical and rehabilitation medicine: an educational review. J Rehabil Med 2011; 43(8): 661−72.
3. *Madden RH, Glozier N, Fortune N, Dyson M, Gilroy J, Bundy A*, et al. In search of an integrative measure of functioning. Int J Environ Res Public Health 2015; 12(6): 5815−32.
4. *Vukomanović A, Popović Z, Durović A, Krstić L.* The effects of short-term preoperative physical therapy and education on early functional recovery of patients younger than 70 undergoing total hip arthroplasty. Vojnosanit Pregl 2008; 65(4): 291−7.
5. *Vukomanović A, Djurović A, Popović Z, Ilić D.* The A-test: reliability of functional recovery assessment during early rehabilitation of patients in an orthopedic ward. Vojnosanit Pregl 2014; 71(7): 639−45.
6. *Vukomanović A, Djurović A, Popović Z, Pejović V.* The A-test: Assessment of functional recovery during early rehabilitation of patients in an orthopedic ward: content, criterion and construct validity. Vojnosanit Pregl 2014; 71(8): 715−22.
7. *Hodkinson HM.* Evaluation of a mental test score for assessment of mental impairment in the elderly. Age Ageing 1972; 1(4): 233−8.
8. *Parker MJ, Palmer CR.* A new mobility score for predicting mortality after hip fracture. J Bone Joint Surg Br 1993; 75(5): 797−8.
9. *Shields RK, Leo KC, Miller B, Dostal WF, Barr R.* An acute care physical therapy clinical practice database for outcomes research. Phys Ther 1994; 74(5): 463−70.
10. *Shields RK, Enloe LJ, Evans RE, Smith KB, Steckel SD.* Reliability, validity, and responsiveness of functional tests in patients with total joint replacement. Phys Ther 1995; 75(3): 169−76; discussion 176−9.
11. *Altman DG, Bland JM.* Diagnostic tests 3: Receiver operating characteristic plots. BMJ 1994; 309(6948): 188.
12. *Akobeng AK.* Understanding diagnostic tests 3: receiver operating characteristic curves. Acta Paediatrica 2007; 96(5): 644−7.
13. *Perkins NJ, Schisterman EF.* The inconsistency of "optimal" cutpoints obtained using two criteria based on the receiver operating characteristic curve. Am J Epidemiol 2006; 163(7): 670−5.
14. *Fischer JE, Bachmann LM, Jaeschke R.* A readers' guide to the interpretation of diagnostic test properties: clinical example of sepsis. Intens Care Med 2003; 29(7): 1043−51.
15. *Jekel JF, Elmore JG, Katz B.* Epidemiology, Biostatistics and Preventive Medicine. 1st ed. Phyladelphia, PA: WB Saunders Company; 1996.
16. *Peacock JL, Peacock PJ.* Oxford handbook of medical statistics. New York: Oxford University Press; 2011.
17. *Hulsbæk S, Larsen RF, Troelsen A.* Predictors of not regaining basic mobility after hip fracture surgery. Disabil Rehabil 2015; 37(19): 1739−44.
18. *Duke RG, Keating JL.* An investigation of factors predictive of independence in transfers and ambulation after hip fracture. Arch Phys Med Rehabil 2002; 83(2): 158−64.
19. *Foss NB, Kristensen MT, Kehlet H.* Prediction of postoperative morbidity, mortality and rehabilitation in hip fracture patients: The cumulated ambulation score. Clin Rehabil 2006; 20(8): 701−8.
20. *Cameron ID, Lyle DM, Quine S.* Accelerated rehabilitation after proximal femoral fracture: a randomized controlled trial. Disabil Rehabil 1993; 15(1): 29−34.
21. *Swanson CE, Day GA, Yelland CE, Broome JR, Massey L, Richardson HR*, et al. The management of elderly patients with femoral fractures. A randomised controlled trial of early intervention versus standard care. Med J Aust 1998; 169(10): 515−8.
22. *Larsen K, Sørensen OG, Hansen TB, Thomsen PB, Søballe K.* Accelerated perioperative care and rehabilitation intervention for hip and knee replacement is effective: a randomized clinical trial involving 87 patients with 3 months of follow-up. Acta Orthop 2008; 79(2): 149−59.
23. *Koval KJ, Chen AL, Aharonoff GB, Egol KA, Zuckerman JD.* Clinical pathway for hip fractures in the elderly: the Hospital for Joint Diseases experience. Clin Orthop Relat Res 2004; (425): 72−81.
24. *Husted JA, Cook RJ, Farewell VT, Gladman DD.* Methods for assessing responsiveness: a critical review and recommendations. J Clin Epidemiol 2000; 53(5): 459−68.
25. *Lee D, Jo JY, Jung JS, Kim SJ.* Prognostic Factors Predicting Early Recovery of Pre-fracture Functional Mobility in Elderly Patients With Hip Fracture. Ann Rehabil Med 2014; 38(6): 827−35.
26. *Hoang-Kim A, Schemitsch E, Bhandari M, Kulkarni AV, Beaton D.* Outcome assessment in hip fracture: evaluation of the practicality of commonly-used outcomes in hip fracture studies. Arch Orthop Trauma Surg 2011; 131(12): 1687−95.

Received on August 19, 2015.
Revised on October 19, 2015.
Accepted on October 22, 2015.
Online First April, 2016.

Appendix 1.

The A-test form

No	Parameters	Day of rehabilitation				
		1st	2nd	3rd	4th	5th
1	From supine to side lying					
2	From supine to sitting					
3	From sitting to standing					
4	Standing					
5	Back to bed					
6	Walking with aides					
7	Use of toalet					
8	Sitting on chair					
9	Walking up and down stairs					
10	Endurance while walking					
	SUMM					

The assessment of patient's ability to perform activity: 0 – if patient didn't perform activity, 1 – if patient was absolutely dependent of therapist help, 2 – if patient performed activity with little therapist help, 3 – patient needed therapist' verbal suggestion while performing activity, 4 – patient performed activity independently but insecurely (needed presence of another person, member of family for example), 5 – patient performed activity independently and securely.	The assessment of patient's endurance while walking: 0 – didn't walk 1 – walked 5 meters (in bed room) 2 – walked 15 meters 3 – walked 50 meters 4 – walked 100 meters 5 – walked more than 100 meters The optimal cut-off for the results of A-test: 1st day of rehabilitation: 7/8, 2nd day: lower – 12/13, upper – 17/18, 3rd day: lower – 13/14, upper – 18/19, 4th day of rehabilitation: 29/30, 5th day of rehabilitation: 34/35.

The lower point of the A-test safely separates the patients with functional disability, while upper point rules out functional disability.