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Prospective study on the efficacy of low-field intraoperative magnetic resonance imaging in neurosurgical operations

Prospektywna ocena przydatności niskopolowego śródoperacyjnego rezonansu magnetycznego w operacjach neurochirurgicznych

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Abstract

Background and purpose: The application of intraoperative magnetic resonance imaging (iMRI) is related to a series of challenges of both a technical and an organizational nature. We present our experience in the application of low-field iMRI in everyday neurosurgical practice.

Material and methods: A group of 58 patients operated on using low-field iMRI was subject to prospective controlled observation. The significance of differences in the range of preparation time, duration and direct operation results between the iMRI group and controls was analysed. The influence of epidemiological and demographic factors and technical aspects related to iMRI application on direct outcome of the surgery was assessed.

Results: Twenty-eight tumour resections using craniotomy, 17 transsphenoidal resections of pituitary adenomas and 13 stereotactic procedures were conducted in the group of 24 men and 34 women operated on using iMRI. The control group was not significantly different in terms of epidemiological and demographic factors. The preparation and operation times were significantly longer in the iMRI group ($p < 0.001$ and $p = 0.002$, respectively). Longer duration of the surgery was not related to an increased frequency of complications. A higher percentage of postoperative improvement in neurological status (31% vs. 14%, $p = 0.045$), lower complication percentage (10% vs. 28%, $p = 0.03$) and

Streszczenie

Wstęp i cel pracy: W pracy przedstawiono pierwsze doświadczenia w wykorzystaniu śródoperacyjnego niskopolowego rezonansu magnetycznego (iMRI) w codziennej praktyce neurochirurgicznej, z uwzględnieniem wyników prospektywnej obserwacji wpływu jego zastosowania na bezpośrednie wyniki operacji.

Materiał i metody: Prospektywnej kontrolowanej obserwacji poddano grupę 58 pacjentów operowanych z wykorzystaniem iMRI. Grupę kontrolną stanowili pacjenci operowani z wykorzystaniem neuronawigacji optycznej bez zastosowania iMRI. Zbadano istotność różnic w zakresie czasu przygotowań, czasu trwania i bezpośrednich wyników operacji pomiędzy grupą badaną i grupą kontrolną. Oceniano wpływ czynników epidemiologicznych, demograficznych oraz aspektów technicznych związanych z zastosowaniem iMRI na bezpośredni wynik operacji.

Wyniki: W grupie 24 mężczyzn i 34 kobiet operowanych z wykorzystaniem iMRI wykonano 28 resekcji guzów mózgu drogą kraniotomii, 17 przezklinowych resekcji gruczolaków przysadki i 13 procedur stereotaktycznych. Czas przygotowań i czas operacji były istotnie dłuższe w grupie iMRI (odpowiednio $p < 0{,}001$ i $p = 0{,}002$). Wydłużenie czasu trwania procedury nie było związane ze wzrostem częstości powikłań. W grupie operowanej z wykorzystaniem iMRI stwierdzono większy odsetek osób z pooperacyjną poprawą

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a similar time of hospitalization (13 ± 7 vs. 12 ± 4 days, $p = 0.33$) were noted in the iMRI group.
Conclusions: The application of low-field iMRI prolongs the duration of neurosurgical procedures but does not negatively influence their safety. It is associated with above-average functional results and a lower percentage of total complications.

Key words: intraoperative imaging, intraoperative magnetic resonance, neurooncology, neuronavigation.

stanu neurologicznego (31% *vs* 14%, $p = 0{,}045$), mniejszy odsetek powikłań (10% *vs* 28%, $p = 0{,}03$) oraz zbliżony czas hospitalizacji (13 ± 7 *vs* 12 ± 4 dni, $p = 0{,}33$).
Wnioski: Zastosowanie niskopolowego iMRI, choć wydłuża czas procedur neurochirurgicznych, nie wpływa negatywnie na ich bezpieczeństwo. Pozwala przy tym uzyskać lepsze od przeciętnych wyniki funkcjonalne oraz mniejszy globalny odsetek powikłań.

Słowa kluczowe: obrazowanie śródoperacyjne, śródoperacyjny rezonans magnetyczny, neuroonkologia, neuronawigacja.

Introduction

Radicality of tumour removal is one of the basic factors influencing the long-term outcome in neurooncological cases. This is the main factor, apart from the degree of histological malignancy of the neoplasm, affecting both progression-free survival time and overall survival time [1,2]. Intraoperative assessment of resection radicality, especially in the case of malignant brain gliomas, is extremely difficult and their localisation in eloquent regions is an additional factor complicating the course of the operation. Obtaining real-time intraoperative images of the brain allows the surgeon to maximize the opportunity to perform optimal tumour resection [3]. For many years, different possibilities for the improvement of intraoperative assessment of tumour removal radicality have been elaborated. They were aimed at increasing the radicality of tumour resection without the risk of permanent deterioration in the patient's neurological status [4,5].

Intraoperative magnetic resonance imaging (iMRI) is a method of intraoperative diagnostics enabling real-time operative navigation and an assessment of the extent of tumour removal as well. According to Black *et al*. [6] intraoperative MRI imaging for monitoring of the course of an operation was introduced to neurosurgical practice over 10 years ago.

Presently, two types of iMRI systems, requiring appropriate preparation of the operating rooms and their back-up facilities, are in use in neurosurgical centres worldwide. The first system is based on the application of high-field resonance (1.5 T or more) generating images of perfect quality, allowing a wider range of intraoperative diagnostics including vascular, functional and metabolic examinations [7-9]. By virtue of the necessity to guarantee the proper technical and personnel back-up for high-yield MR, the decision on apparatus installation is usually undertaken at the hospital design stage. The factor that undoubtedly considerably influences the low prevalence of this kind of installation, especially in Europe, is its high cost [10]. Thus, there is an interest in low-field MR machines that do not require additional infrastructure, are cheaper to install and operate, and ensure images of a quality enabling navigation and decisions to be taken during the operation [3,11]. The application of intraoperative imaging increases the degree of procedure complication, often requires additional personnel involvement, and may prolong the time of the preparation for the operation and duration of the operation itself [3,12]. There are not many papers in the available literature that consider the issue of the technical aspects of iMRI application on operation security and direct treatment results. The aim of the paper was a prospective assessment of the results of preliminary experience on the application of low-field iMRI PoleStar N20 during intracranial pathology operations in the Department of Neurosurgery at Wroclaw Medical University.

Material and methods

The patients who were operated on during the period from August 2008 to October 2010 in the Department of Neurosurgery at Wroclaw Medical University using iMRI (PoleStar N20, Medtronic Navigation, Louisville, CO, USA) were subject to prospective controlled observation. The mobile iMRI apparatus generated a constant magnetic field of an intensity of 0.15 T enabling examinations in T1, T2 and FLAIR sequences of a 16 × 9 cm field of view (FOV) to be conducted. All the procedures took place in an operating room adapted for iMRI application. The room was equipped with filters and screens reducing the influence of external