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Hip joint implant component size planning using PACS software

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Introduction The relevance of the problem is due to the growing requirements for storage and exchange of digital images in medicine and hip arthroplasty quality improvement. It is necessary to prove the higher clinical efficiency of the PACS system in planning the sizes of joint implant components. **The aim** of the work is a comparative assessment of the quality of planning the sizes of acetabular and femoral components using the PACS system and without it. **Methods** The material of the study was data on the sizes of acetabular and femoral components of the hip joint implant used in 2012 and in 2014-2017. The method of study is the choice of cases of surgical treatment of primary coxarthrosis. **Results** The results of the study showed a stable proportion of discrepancies by one or two sizes in 82.6–88.7 % of the total number of the components having differences in sizes. Since 2016, differences of measurements ±1 size were not revealed. The portion of absent discrepancies increased in 2017 (49.5 %); the portion of differences in the size of one of the components decreased from 51.5 % to 40.6 %, of both – from 30.3 % to 9.9 %. Deviations by more than two sizes decreased from 15.9 % to 11.8 %. Positive dynamics was more observed when the PACS system started to operate in 2014. **Conclusion** The study showed a complete correspondence in the sizes of the components planned and used in 49.5 % of cases when PACS was applied (2.2 times more than by “manual" planning). The difference in the size of one component was reduced by 14 %, of both – by 3.1 times, and of "more than 2 sizes"– by 1.3 times. Divergence of "less than one size" was excluded. Differences in one to two sizes were constant in the study period and probably are not related to the method of planning. Our results confirm that the quality of the selection of the dimensions of implant components improved after the introduction of the PACS system.

Keywords: joint replacement planning, radiological diagnosis, digital medical images, medical information systems

INTRODUCTION

Picture Archiving and Communication System (PACS) of storage and transmission of medical digital diagnostic images and medical information has been used in medical practice for over 45 years. This system was first introduced in Switzerland in 1970; then in 1982–1983, PACS was installed in the laboratory at the University of Kansas City, and *Fujifilm* began producing CR systems, the advantage of which was the transition from film radiography to fully digital radiographic images The main merits of digital radiography are the speed with which the image becomes available for medical analysis and the possibility of mathematical processing in order to improve quality. However, accumulation of a large amount of information in the computers of the doctor or laboratory assistant prompted to create a system for storage of images. At that time, digital devices were of low quality, which was the impetus for creating “hybrid” PACS systems capable of working with digital images, as well as of storing information about film shots [1].

Radiology is the source of the maximum amount of digital data and the most demanding user of modern hardware and software systems to work with these data. At present, the speed of access to stored data on the one hand and the capacity of devices for archiving constantly increase. On the other hand, research methods continuously improve; the speed of data collection and the resolution of the obtained images enhance [2–4]. Introduction of information technologies made the work efficient, enables to avoid errors by introducing the information about patients and to save on film production (expensive films, chemical reagents, processing machines, organization and maintenance of film archive), to improve the quality of diagnostic and therapeutic assistance. The use of such systems in medicine provides storage of a large number of medical images and quick access to them, and also opens up new possibilities in the quality of interaction of regional clinics with large medical centers and international medical associations within telemedicine [5–8].

Today, the decision to equip medical organizations (MOs) with PACS systems is taken in some countries at the state level (Great Britain, Finland) in relation to large networks of institutions. In Sweden, for

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example, almost all MOs are equipped with PACS systems [8].

The introduction of PACS systems in Russia is at the development stage. In some MOs, PACS systems have been already fully or partially installed [9].

There is no doubt about the demand for PACS systems in traumatology and orthopedic institutions, in particular, for hip joint arthroplasty (THA), where the most precise selection of implant components is required at the planning stage. The quality of arthroplasty is directly dependent on the congruence of the surfaces of the components to the joint bone base, which is maximally achieved only with the help of measurements carried out by a computer program. PACS also provides the possibility of re-planning the size of the implant directly during the intervention, which further improves the accuracy of the selection of its components, and postoperative radiographic control. The use of individual surgical templates in selecting the implant size contributes to its durability and survival time, reducing the number of mechanical complications [10].

Since 2009, the Federal Centre for Traumatology, Orthopedics and Joint Replacement of the Ministry of Health of the Russian Federation (Cheboksary) has operated a radiological information system (RIS) that provides the transfer of graphic images from X-ray machines, computer and magnetic resonance devices to electronically managed medical records of patient via the Dicom server [11, 12]. In the preoperative period, the sizes of the implant components for THA were determined visually in radiographs of the pelvis in the frontal plane with the capture of both joints using surgical templates. Since 2013, planning of operations with the installation of metal implants has been carried out automatically using the Centricity PACS-IW system (viewing and image processing). The system processes X-ray data, CT and MR images, and ultrasound scans. The TraumaCad module is capable to perform both automatic and manual planning of the operation using digital images on the screen (measurements, modeling of arthroplasty, osteotomy, osteosynthesis, etc.). With the introduction of PACS, there is no need to select individual parameters of shooting (**Fig. 1**).

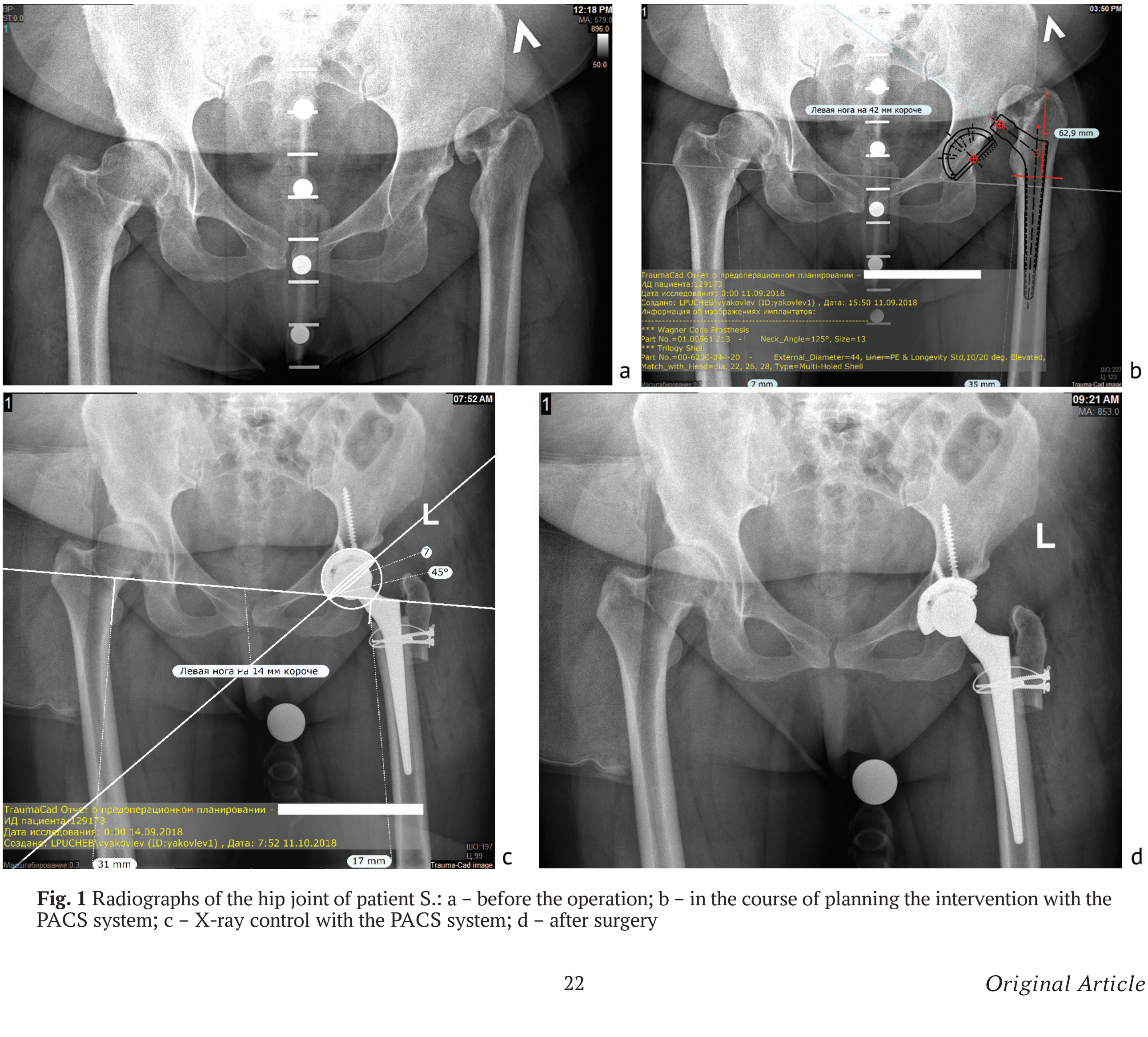

Fig. 1 Radiographs of the hip joint of patient S.: a – before the operation; b – in the course of planning the intervention with the PACS system; c – X-ray control with the PACS system; d – after surgery

As a result, there was no need to select individual shooting parameters (the shooting time decreased to about 5 minutes per patient) and defective film shots almost disappeared, making up to 0.1 % of all studies. The system, connected to telecommunication services via personal access, directly transmits data to automated workplaces of all specialists, provides scaling and viewing the image, and adjusting light and color vision individually for each doctor, as well as introducing the data into the medical information system (MIS) after having drawn up a plan, edit it and etc.

Automatic calibration of the X-ray images obtained significantly saves the time of the X-ray laboratory workers in preparing the patient for the study (about 5 minutes per patient). The time saved in 2016 amounted to: 31583 examinations × 5 min = 2631 hours, and in 2017 it was 2813 hours of working time for 33756 examinations.

The organization of information support of the radiographic examination process and planning of surgical interventions based on the new PACS system integrated with the MIS reduced the time spent at medical meetings to coordinate the tactics of surgical interventions from 40 to 20 minutes. Taking into account the fact that meetings are held every working day (on average, 240 times a year), and 20 specialists take part in them, the potential time saving by the formula is:

20 minutes × 240 × 20 (number of specialists) = 96,000 minutes or 1600 hours.

The system provides physicians with more freedom, reduces the time for planning an operation, improves the accuracy of the installation of metal constructs, the effectiveness of procedures and facilitates monitoring. In addition, the use of the system reduces the expenditures of the Centre for radiographic films, consumables, equipment and data storage annually in the amount of about 2 million rubles [12].

It remains to confirm that the quality of arthroplasty planning using the PACS system has improved in comparison with the previous method of planning the sizes of implant components.

Purpose of the study To assess the effectiveness of various ways of planning the sizes of the acetabular and femoral components of hip joint implants (using the PACS system and without it) by comparing the correspondence of the planned sizes to the sizes of the components installed during the operation.

MATERIAL AND METHODS

Preoperative and intraoperative measurements of the sizes of the acetabular and femoral components in patients who received surgical treatment with THA were the material for a retrospective continuous study. The study analyzes the correspondence of the assumed and actual sizes of the acetabular and femoral components of the hip implant in the observation groups in 2012 and in the period 2014–2017. Implants of 2013 were excluded from the study as it was an adaptation period with low data reliability due to the transition to operating the PACS system.

All the information about the technical characteristics of implants should be introduced by orthopedic surgeons in the MIS. The electronic record "Preoperative epicrisis" contains data on the dimensions of the components planned for use. The dimensions of the components installed during the interventions are introduced in the "Protocol of surgery".

The data from the MIS were automatically downloaded as EXCELL files. The samples included all clinical cases with primary coxarthrosis at Orthopedic Department No. 1. To ensure a unified approach to the measurements, the data of one orthopedic surgeon were taken into account. Primary coxarthrosis was chosen as a criterion for selecting patients into the observation groups due to its "standard features" and absence of pronounced deformations of the acetabulum (ICD 10 codes – M16.0, M16.1, M84, S72). Planning of surgical tactics and sizes of the components in secondary coxarthrosis with pronounced acetabular deformities requires a more complex individual approach and cannot serve as a planning standard; therefore patients diagnosed with it were excluded from the study.

Deviations of the actual sizes from the planned ones were calculated without taking into account the differences in higher or lower values, as well as without considering the requirements for the type of components (acetabular or femoral). The grouping was conducted by "no divergence" and "there are divergencies". In case of discrepancies, two approaches were applied: 1) number of components (one / both), by the degree of deviations detected: "one to two sizes", "more than two sizes", "less than one size". Since the "size step" of the implant components of any model (manufacturer) is 2 mm (the difference in the subsequent size from the previous one by 2 mm), we took this "size step" as one size and neglected implant modifications.

Statistical processing of the data was performed using the Descriptive Statistics of Microsoft EXCEL 2007 software package.

RESULTS

Statistical data of the Centre shows an annual increase in the number of THA operations (**Fig. 2**).

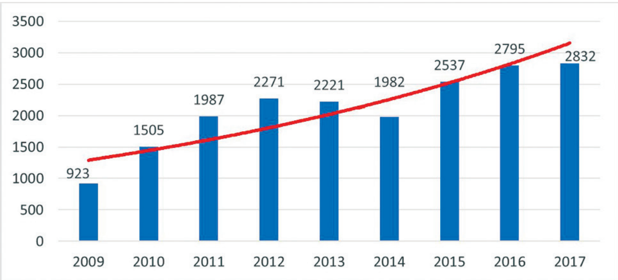

Fig. 2 Number of THA interventions performed in 2009–2017

The number of observation units (clinical cases) over the years ranged from 89 to 225. The average age of patients ranged from 56.0 ± 1.0 to 59.5 ± 1.2 years and the equal ratio of men to women included in the study was practically similar (Table 2).

Table 2

Years	Number of patients	Mean age, years	Males		Females	
			number	%	number	%
2012	89	57.2 ± 1.2	49	55.1	40	44.9
2014	101	59.5 ± 1.2	48	47.5	53	52.5
2015	146	56.0 ± 1.0	66	45.2	80	54.8
2016	225	56.9 ± 0.8	113	50.2	112	49.8
2017	202	57.5 ± 0.9	91	45.0	111	55.0

The percentage of cases without discrepancies between the planned and actual sizes of the implant components increased in 2017 to 49.5 % (almost half of the cases). Moreover, positive dynamics were more pronounced from the moment of active operation of the PACS program in 2014 (2012 – 22.5 %; 2014 – 33.7 %). Differences in the size of one of the components in the study period (plan / fact) were recorded less frequently. In 2012, it was 47.2 % while in 2014 – 51.5 % and in 2017 – 40.6 %. Mismatch of both components decreased more significantly, from 30.3 % in 2012 to 9.9 % in 2017, with a sharp reduction in differences noted since 2014 (**Fig. 3**).

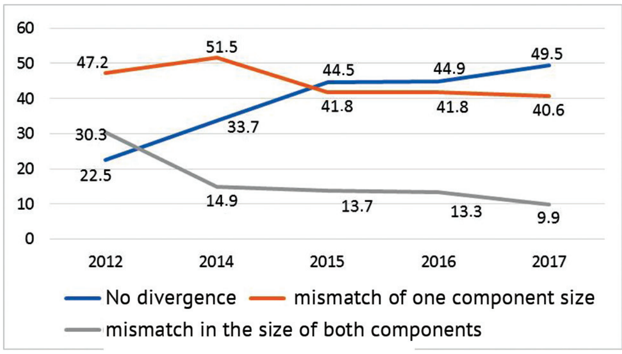

Fig. 3 Proportion of differences between the planned and the actual size of implant components in 2012 and in 2014–2017 (%)

Cases of measurement discrepancies of ± 1 size were revealed in 1.4 % in 2012 and in 1.5 % in 2014. Since 2016, not a single case has been identified. The discrepancies of 1–2 sizes were within 82.6–88.7 % of the total number of components with differences in the sizes. The share of deviations by more than 2 sizes decreased from 15.9 % in 2012 to 11.9 % in 2014, and made up 11.8 % in 2017 (**Fig. 4**).

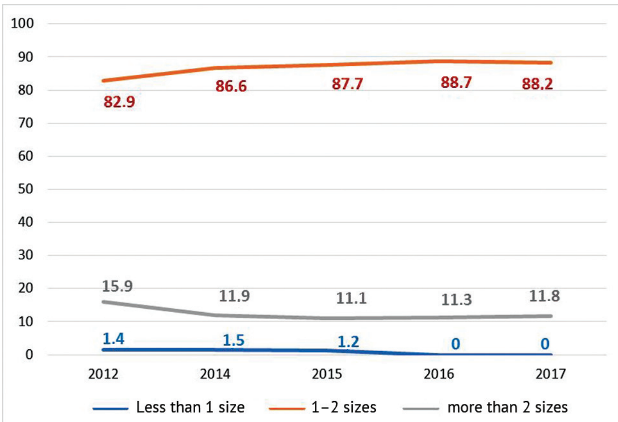

Fig. 4 Deviations of the size used from the planned ones in 2012 and 2014-2017, %

DISCUSSION

Both our results and the results of our colleagues confirm the positive dynamics in the quality of the selection of implant component sizes for THA with the introduction of the PACS system [2, 3, 6].

The overall decrease in the percentage of discrepancies between the planned and actual characteristics of the acetabular and femoral components was also noted by other authors [4, 5].

Difference in the size of one implant component was reduced by 14 % and difference in the size of both components at a time by 3.1 times. Since 2016, discrepancies in the sizes of components in the “less than one size” grouping have not been registered. Discrepancy of more than two sizes decreased 1.3 times. The number of cases of “perfect” sizing more than doubled.

Positive results obtained by us confirm the literature data [2–6] as well as earlier opinions of other colleagues on improving the quality and efficiency of medical organizations with introducion of PACS system (I. N. Gipp, 2006) and high diagnostic value of the images obtained using computer technology PACS (A. S. Osadchy, 2009).

This gives grounds to recommend the PACS system to medical organizations for its wider use in various areas of clinical medicine [9, 10].

However, in traumatology and orthopedics, the issue of the reasons of persistence of discrepancies in the sizes of implant components by 1–2 sizes (from the total number of cases with discrepancies) even after the introduction of PACS requires further study [12]. We suppose that they are not related to the method of component size planning (automatically or manually) and may be due to a certain proportion of patients with radiographically not visualized individual features of the bone tissue (errors in the diagnosis of primary coxarthrosis are possible).

CONCLUSIONS

A comparative analysis of the effectiveness of planning the size of the acetabular and femoral components for THA using the PACS system and without it by assessing the compliance of the planned dimensions with the sizes of the components installed during the operation showed the following:

– in almost half of the cases starting the use of the PACS system in 2014, the components of the hip joint installed in the patients with primary coxarthrosis had the same dimensions as planned for use in preoperative calculations, which is 2.2 times higher than with "manual" planning;

– increased number of cases of "ideal" selection of the sizes of the implant components using the PACS system as well as the revealed tendency to reduction of the number of discrepancies between the planned and actual sizes of the components indicates the advantages of planning with the help of the PACS system and an increase in the quality of THA planning.

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