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original article

The evolution of robotic arm-assisted arthroplasty in Greece

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SUMMARY: **The evolution of robotic arm-assisted arthroplasty in Greece.**

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Background. *The robotic arm-assisted (Mako) arthroplasty was introduced in Greece in January 2014, through the years of financial crisis. The purpose of this study is to demonstrate its evolution per procedure throughout the years.*

Materials and methods. *Data regarding type of procedure: partial knee arthroplasty (PKA), total knee arthroplasty (TKA) and total hip arthroplasty (THA) were collected from the official distributor of the Mako platform in Greece. The number of Mako arthroplasties were calculated annually and monthly per procedure type from January 2014 to December 2018.*

Results. *A total of 1081 robotic arm-assisted arthroplasties have been performed in Greece in two private hospitals. Mako cases showed overall 163.06% increase, while THA showed 235.1% increase, during the study period. On the other hand PKA showed 61% decrease, while in during one year (2017-2018) TKA showed 402% increase.*

Conclusions. *Introducing robots into the orthopedic operating theater may improve precision, could lead to lower complication rates and finally may offer higher patient satisfaction scores. However, the total growth of robotic arm-assisted arthroplasties in Greece should be interpreted with caution, since all surgeries were performed in private institutions and, therefore, the economic burden of these procedures may have been withstood by specific social class patients.*

KEY WORDS: Robotic arthroplasty - Mako arthroplasty - Robotic orthopaedics - Robotics - Robotic arm assisted surgery Greece.

Introduction

Joint replacement techniques and instrumentation have undergone a tremendous improvement throughout the years (1). The robotic arm-assisted (Mako) arthroplasty represents an example of how technology is transforming joint replacement surgery. Preoperatively, a super fine 0,6 mm slice computer tomography (CT) scan is performed consisting of the hip, knee and ankle joint, so that the mechanical axis and detailed anatomy may be evaluated. Then the 3 dimension (3D) model of the patient's unique joint anatomy is generated. This virtual model is used by the system software, allowing the orthopaedic surgeon to create the patient's preoperative plan. Intraoperatively, the robotic arm-assisted system assists the surgeon to stay within the planned boundaries, while it assists the surgeon to adjust the plan if necessary (2, 3). Through the combination of visual auditory and haptic feedback, any possible human error driving the burr out of the operation plan limits in any of the 3 dimensions is immediately blocking the system (2, 3).

The first robotic arm-assisted procedure was a partial knee replacement performed in June of 2006 by Dr Martin Roche. Since that time, over 100,000 robotic arm-assisted hip and knee replacement procedures have been performed worldwide (4).

The robotic arm-assisted arthroplasty was introduced in Greece in 2014 during the years of financial crisis. The purpose of this study is to demonstrate its evolution per procedure throughout the years and if possible correlate its progress with social-economic factors in Greece.

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Methods

The present is a retrospective study. All procedures performed with the Robotic Arm Interactive Orthopedic System (RIO; MAKO Stryker, Fort Lauderdale, Florida) were recorded. Data regarding type of procedure: partial knee arthroplasty (PKA), total knee arthroplasty (TKA) and total hip arthroplasty (THA) were retrospectively and anonymously collected from the prospectively functioning electronic system of Rontis Hellas, the official distributer of the Mako system in Greece. The number of Mako arthroplasties cases were calculated annually and monthly per procedure type from January 2014 to December 2018.

Robotic arm-assisted arthroplasty was introduced in Greece in January 2014, while 2 centers (both private institutions) have, so far, installed the Mako platform.

Results

From 2014 to 2018 a total of 1081 robotic arm-assisted (Mako) arthroplasties have been performed in Greece. Figure 1 highlights the progress of robotic arm-assisted arthroplasties, annually, per procedure type, during the study period. Mako TKA began in October 2017 (50 cases), while in 2018 a total of 251 Mako TKA were performed. Through this 5-year period a total of 461 PKAs and 319 THAs have been performed. In 2014 a total of 157 robotic arm-assisted arthroplasties were performed (PKA: 123; 78.3%, THA: 34; 21.7%); in 2015 a total of 239 (PKA:163; 68.2%, THA:76; 31.8%); in 2016 a total of 83 (PKA:63; 75.9%, THA:20; 24.1%); in 2017 a total of 189 (PKA:64; 33.9%, THA:75; 39.6% and TKA:50; 26.5%) and in 2018 a total of 413 (PKA:48; 11.6%, THA:114; 27.6% and TKA:251; 60.8%). During the study period the to-

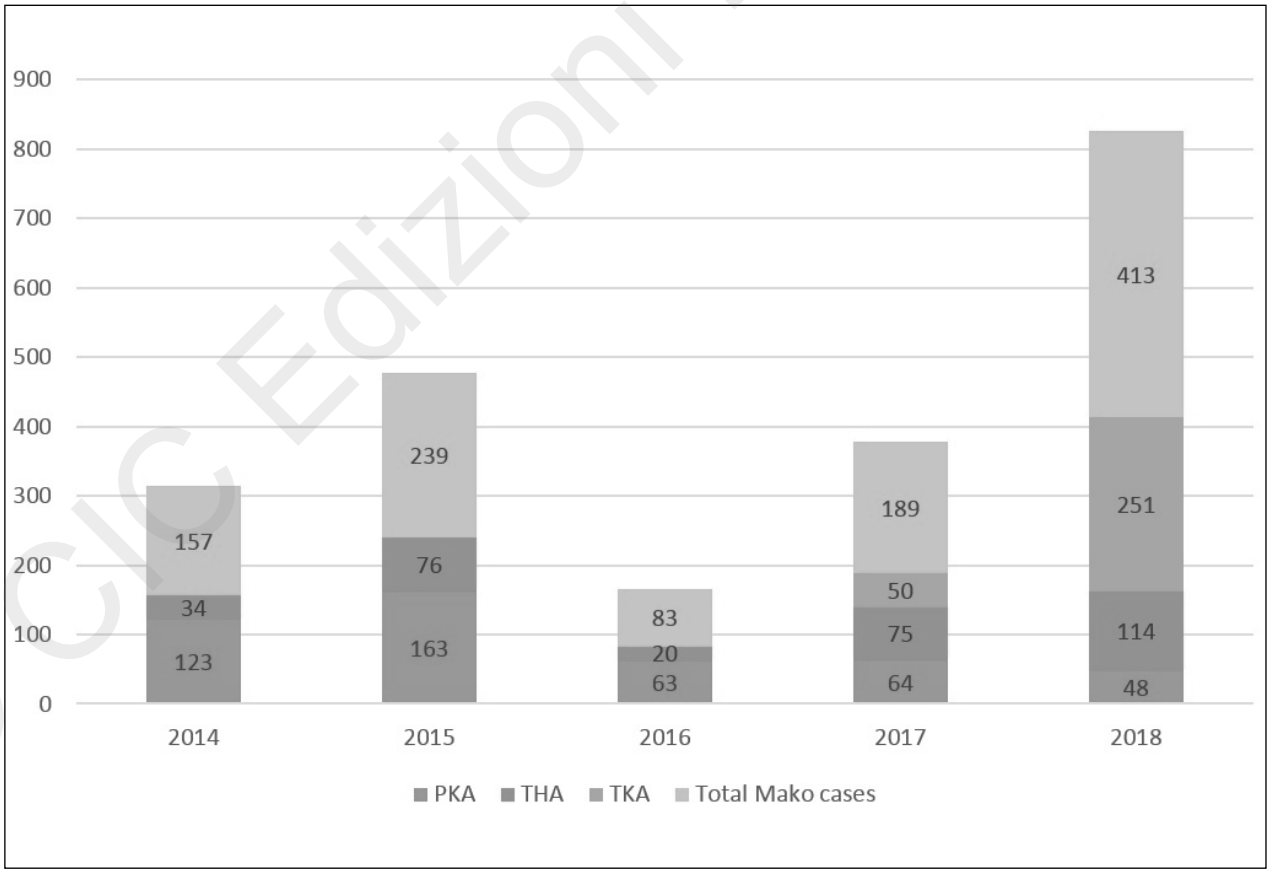

Figure 1 - Mako cases performed in Greece between 2014 and 2018 per year. PKA: partial knee arthroplasty, THA: total hip arthroplasty, TKA: total knee arthroplasty.

tal Mako cases showed 163.06% increase, while THA 235.1% increase. On the other hand PKA showed 61% decrease, while in during one year (2017-2018) TKA showed 402% increase.

Figure 2 highlights the number of Mako cases per month, per procedure type, during the study period. Total Mako arthroplasties per month performed in Greece were 14.3 (PKA:11.2, THA:3.1) in 2014; 21.7 (PKA:14.8, THA:6.9) in 2015; 7.5 (PKA:5.6, THA:1.8) in 2016; 17.2 (PKA:5.8, THA:6.8 and TKA:4.5) in 2017 and 37.5 (PKA:4.4, THA:10.4 and TKA:22.8) in 2018.

Discussion

Robotic arm-assisted (Mako) arthroplasty was introduced in Orthopaedic surgery in 2006 (5). Mako arthroplasty represents a semi-active system. It requires the surgeon's involvement, but simultaneously provides haptic and visual feedback, usually tactile, to augment the surgeon's control and theoretically operation safety. These semi-active systems provide passive haptic restraints for surgical resection (5, 6). The surgeon may not, for instance, burr bone outside of the preset volumetric parameters, confining the treatment to only the planned level of resection in 3D (2, 3, 5). Mako robotic arm-assisted system is the only available, worldwide, semi-active platform, while it represents the only FDA approved system with all 3 applications; partial knee, total knee and hip arthroplasty.

The human judgment errors made in manual arthroplasties could be related to poor anatomy visualization and lack of stereometric guidance. The high rate of short term complications such as dislocation, impingement, persisting pain, or long term complications of wear and loosening, created the

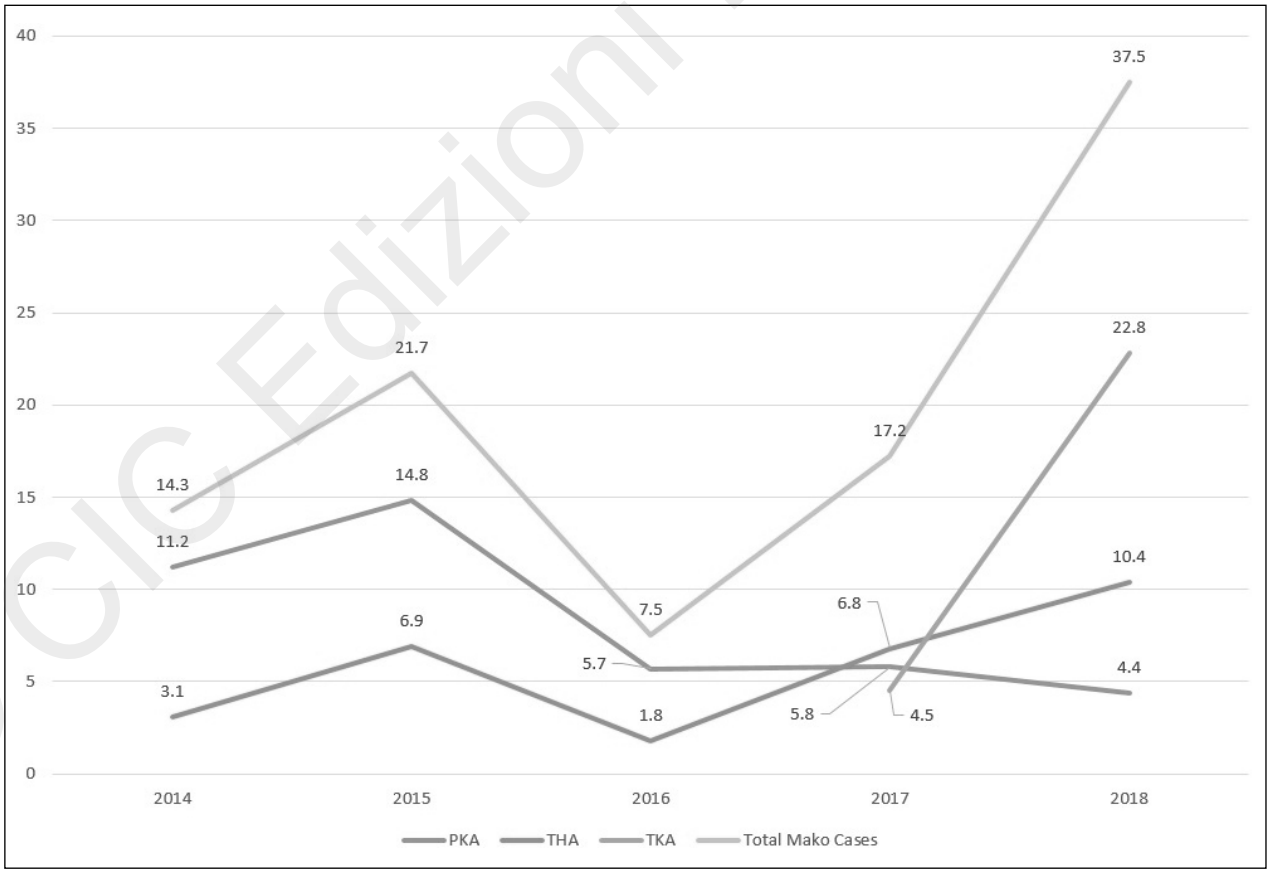

Figure 2 - Mako cases performed in Greece per months between 2014 and 2018. PKA: partial knee arthroplasty, THA: total hip arthroplasty, TKA: total knee arthroplasty.

need of introducing this haptic system in joint arthroplasty (3, 5). Mako platform may minimize the human errors by providing quantitative knowledge which changes qualitative judgment decisions to accurate and precise ones. The Mako platform offers precision of bone preparation, quantitative knowledge of component position and biomechanical reconstruction of limb length and offset (1, 5, 6, 7). A series of studies revealed that, when compared to manual techniques, the robotic platform has increased accuracy in recreating the posterior tibial slope and coronal tibial alignment in PKAs and TKAs (8-12). The robotic system significantly decreases the learning curve observed during the adoption of PKAs with traditional instrumentation (13).

The robotic arm-assisted arthroplasty was introduced in Greece in 2014, during the years of financial crisis. Although Greece is a small country with 10 million inhabitants and represents only the 2% of the European Union population, it was the second country in Europe following Italy to introduce the Mako robotic arm-assisted system. Greece has been affected by the fiscal turmoil beginning in 2008 more than any other European Union country (14). Unemployment, income reduction and poverty were among the most serious consequences of the crisis, resulting in severe austerity measures which devastated the spending power of the Greek health system, while simultaneously magnifying its existing issues (14). Notwithstanding the crisis, the total performance of robotic arm-assisted (Mako) grew significantly during the study period. It is of note that Mako arthroplasties showed a decrease (65.3%) in 2016, when compared to those of 2015. This could be attributed to the implementation of capital controls in the country at the last semester of 2015. It is of note that 2016 represents the most difficult year in Greek economy, since financial uncertainty, high poverty rates and heavy taxation, as well as capital limitations, lead to a huge wave of migration (especially scientists and highly educated citizens) to Europe and other countries (14).

Robotic arm-assisted TKA was the last available application, while FDA approval for TKA came in 2017 (5). In October of the same year, the procedure was also introduced in Greece, showing 402% increase in just one-year time. It should be noted that this increase may be false, due to the fact that Mako TKA was performed only during the last three months of 2017. Furthermore, these 3 months should not be considered representative, since during that time the first Mako TKA cases were performed, therefore, neither surgeons were accustomed with the procedure, nor the patients informed about this surgical option.

The higher percentage of PKA during the first years of the study (78.3% in 2014 and 68.2% in 2015 of total Mako arthroplasty cases) could be explained by the fact it was the only available robotic knee application until 2017. Furthermore, the robotic arm-assisted surgery attracted a big population of patients with need for PKAs that were reluctant to proceed to manual operation, due to the relative high complication rates (15). The introduction of the TKA application in Greece in October 2017 restored the real percentage of PKAs among MAKO cases the following year. In 2018 PKAs represented 16% of Mako knee procedures and 11.6% of total arthroplasty cases. This percentage is higher than the one recorded in manual knee arthroplasty, estimated around 9% or less of cases (15). This higher percentage of PKA may be the result of the confidence of the Mako surgeons, since the patients selection is not influenced from the technical problems and the complications of the manual operation.

The total growth of robotic arm-assisted arthroplasty through this 5-year period (2014-2018) in Greece should be interpreted with caution, since all surgeries were performed in private institutions. Hence, it may be implicated that the economic burden of these procedures was withstood by specific social class patients. Nevertheless, in an unwelcoming and uncertain financial environment, robotic arm-assisted arthroplasty technology made its debut successfully and recorded increase in the number of procedures performed throughout these five years.

Introducing robotics into the orthopedic operating theater may improve precision, lead to lower complication rates and offer higher patient satisfaction scores (1, 4, 5). However, the ultimate acceptance of robotic arm-assisted arthroplasty into everyday orthopaedic practice will mainly depend upon

its cost effectiveness. A study has shown that when total cost of care is considered and Markov decision analysis is performed, robotic arm-assisted surgery is actually more cost effective than manual surgery, if the total annual cases are more than 94 and failure rates are less than 1.2% at 2 years follow-up (5, 16). The costs of a robotic system can also be counterbalance by decreased hospital length of stay and projected savings on a costly revision from a manual operation. Hospitals must also consider the potential increase in volume of patients attracted to the facility by this new technology (5, 17, 18).

Conclusions

Although no robotic arm-assisted arthroplasty is currently performed in the public healthcare sector, its steady adoption and acceptance will embolden patients and surgeons to its wider use in the context of future economic regrowth in the Greece. The robotic arm technology expansion in Greece may also represent the overcoming of the financial disaster of the last years.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the Authors.

Conflict of interest

K Dretakis is an International Trainer for Styker. C Koutserimpas declares no conflict of interest.

Authors' contributions

CK for the literature search and analysis, and manuscript writing. KD for the final manuscript revision. All Authors have read and approved the final manuscript.

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