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ONLINE FIRST

International Orthopaedics

ISSN 0341-2695

International Orthopaedics (SICOT)
DOI 10.1007/s00264-020-04480-6

Springer

International Orthopaedics
https://doi.org/10.1007/s00264-020-04480-6

ORIGINAL ARTICLE

Surgery trends for osteonecrosis of the femoral head: a fifteen-year multi-centre study in Japan

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Received: 14 August 2019 / Accepted: 15 January 2020

Abstract

Purpose The most appropriate procedure and at what type and stage of osteonecrosis of the femoral head (ONFH) these procedures had been argued. We attempted to clarify the trend in surgical operations with respect to the age of patients, type classification, and stage of ONFH over a period of 15 years by using the multi-center sentinel monitoring system in Japan.
Methods We evaluated the hips of 3844 patients using this system in three phases of every five years from 2003 to 2017. We classified the surgical procedures as osteotomy (OT), hemiarthroplasty (Hemi), and total hip arthroplasty (THA). We assessed the trend in age, type classification, and stage of ONFH over three time periods; "early," and the "late." We calculated the proportion of surgeries for ONFH in each period. We used the Cochran-Armitage test to evaluate trends in proportion of two levels of characteristics across three time periods.
Results The proportion of younger patients significantly decreased. The proportion of OT and Hemi decreased over time, while the proportion of THA increased. The proportion of patients with types C1 and C2 who underwent OT and Hemi decreased over time. In contrast, that of THA increased. The proportion of patients who underwent OT and Hemi significantly decreased; the proportion of patients who underwent THA significantly increased over time at all stages.
Conclusions In Japan, the younger patients underwent surgery for ONFH decreased. The patients who underwent OT and Hemi for ONFH decreased, while that of THA increased over time.

Keywords Osteonecrosis of the femoral head · Temporal trends · A multi-centre hospital-based sentinel monitoring system · Type · Stage

Introduction

Osteonecrosis of the femoral head (ONFH) often progresses to arthropathy, which leads to pain and functional loss of the ability to perform daily activities [1]. Once the stage of ONFH progressed, there have been few effective conservative treatments for ONFH; various surgical treatments have been performed, including joint-preserving and joint-replacing procedures. There are numerous reports regarding the indications and treatment outcomes of these procedures; however, controversy persists regarding the most appropriate procedure and the type and stage of ONFH at which these procedures should be performed. In Europe and the USA, core decompression is considered useful for ONFH [2], and several studies regarding the usefulness of various osteotomies for ONFH have been conducted in Japan [3, 4]. Few studies have evaluated the trends in surgical treatment for ONFH over time. Johnson et al. reported that the proportion of total hip arthroplasty (THA) increased and that of joint-preserving procedures

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00264-020-04480-6) contains supplementary material, which is available to authorized users.

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Published online: 23 January 2020

decreased among all surgical procedures for ONFH in the USA from 1992 to 2008 [5]. However, the authors did not track the patients' ages at the time of surgery, size of the necrotic lesion of the femoral head, or depth of collapse of the subchondral bone because the study was based on a national institute health database. Age is one of the most important factors influencing the surgical indications for patients with ONFH because the rate of revision for young patients who have undergone THA was reported to be relatively high [6]. Some studies reported that the size of the necrotic lesion and depth of collapse affected the clinical outcomes and joint survival rate for patients undergoing osteotomy (OT) [7, 8]. We built a multi-centre sentinel monitoring system in Japan starting in 1997. This system records the age of patients with ONFH, type classification, and stage of ONFH. The purpose of the present study was to track the trend in the age of patients, type classification, and stage of ONFH at the time of surgery in Japan using our system from 2003 to 2017.

Materials and methods

Since 1972, the Ministry of Health, Labour and Welfare in Japan has conducted a special program that tracks intractable rare diseases that do not have clear mechanisms of onset or standardized treatments. The program is designed to remove the burden of medical expenses for patients with intractable diseases and to promote research. The research committee on ONFH, one of the assigned intractable diseases, was established in 1975 and consisted of hip surgeons and experts in epidemiology, biology, and genetics. In June 1997, the research committee on ONFH started a multi-center hospital-based sentinel monitoring system to elucidate descriptive epidemiology. Thirty-eight hospitals were participating in the monitoring system in April 2018, and the system is ongoing.

The monitoring system consists of two kinds of registries: for ONFH patients who are newly diagnosed and for ONFH patients who underwent surgery. When these patients are identified at the participating hospitals, patients' characteristics are reported to the system. Summary of the data from newly diagnosed ONFH patients has been reported previously [9]. In this study, we used the database of ONFH patients who was performed surgery, as of April 2018. The study protocol was approved by the ethics committees of each participating hospital.

The diagnosis, type, and stage classification of ONFH were determined based on the 2001 criteria that was established by the Japanese Ministry of Health, Labour and Welfare [10] (eFig. 1). The classification scheme of necrotic lesion consists of four types (A, B, C1, and C2) and is based on the central coronal section of the femoral head on T1-weighted images on magnetic resonance imaging (MRI) or the anteroposterior radiographs. The weight-bearing portion is defined as the area lateral to the mid-vertical line through the acetabular edge and the teardrop bottom. Type A lesions occupy the medial one-third or less of the weight-bearing portion. Type B lesions occupy the medial two-thirds or less of the weight-bearing portion, and types C1 and C2 lesions occupy more than the medial two-thirds of the weight-bearing portion; however, type C2 lesions extend laterally to the acetabular edge, whereas type C1 lesions do not. In stage 1, there are no specific findings of osteonecrosis on radiographs; however, specific findings are observed on MRI, bone scintigram, and histology. In stage 2, demarcating sclerosis is seen without collapse of the femoral head. In stage 3, collapse of the femoral head, including the crescent sign, is seen without joint-space narrowing, and mild osteophyte formation of the femoral head or acetabulum may be observed. In stage 3A, collapse of the femoral head is less than 3 mm. In stage 3B, collapse of the femoral head is 3 mm or more. In stage 4, osteoarthritic changes are observed. The treatment procedures were determined by each institute. The study protocol was approved by the ethics committees of each participating hospital.

Data collection

We used a structured form to collect patient information, including demographics and name of surgery. The form included the following basic information: date of birth, gender, date of diagnosis, date of surgery, and the type and stage of ONFH before surgery. We classified the surgical procedures as OT, hemiarthroplasty (Hemi), THA, and others. OT included anterior rotational osteotomy [11], posterior rotational osteotomy [12], and curved intertrochanteric varus osteotomy [13]. Others included vascularized iliac bone graft [14], bone graft with free vascular grafting [15], and transplantation of bone-marrow-derived mononuclear cells [16].

Data analysis

We analyzed data from 4848 hips from January 1997 to December 2017. Figure 1 shows the flowchart of the selection process. Because the definition of type classification and stage of ONFH changed and we changed the questionnaire in 2003, we could not be used the previous data. We collected data on patients undergoing surgery from 2003 to 2017. Patients undergoing revision arthroplasty (82 hips), data missing (57 hips), implant removal (67 hips), and patients < 15 years of age (5 hips) were excluded to avoid possible inclusion of patients with Perthes disease [9]. After these patients were excluded, 3844 hips remained for further analysis.

Thirty-seven facilities participated in the study from 2003 to 2017. The date of surgery was further divided into five year intervals according to a previous study [9]; therefore, we assessed the trend in age, type classification, and stage of ONFH over three time periods: the "early" period, 2003–2007; the "middle" period, 2008–2012; and the "late" period,

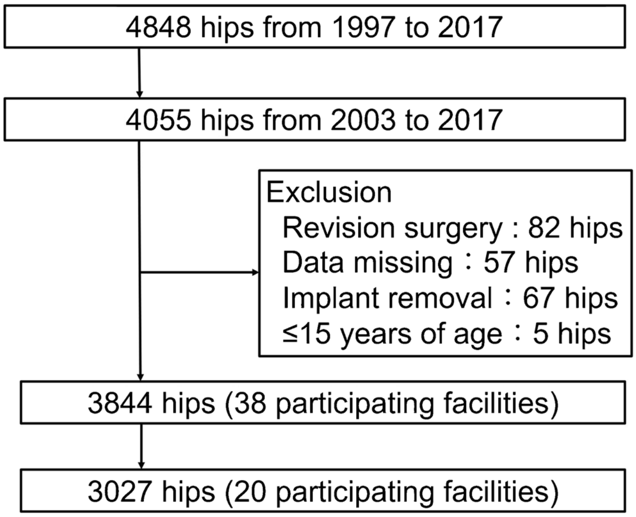

Fig. 1 Flowchart of patient selection

2013–2017. First, we calculated the total number of procedures for ONFH. Second, we analyzed the type and stage of ONFH. Third, we examined the gender and age distribution (16–39 years; 40–60 years; over 60 years) for each type of surgery. All analyses were performed according to the date of surgery, not the reporting date.

In order to evaluate the potential bias of facilities newly participating in the monitoring system, we conducted an additional analysis by limiting the data to those collected by 20 facilities that regularly reported patients throughout the study period.

The Jonckheere-Terpstra test was employed to test the trends of the continuous variables across the three time periods (early/middle/late). We used the Cochran-Armitage test to evaluate the trends in the proportion of two levels of characteristics across three time periods (early/middle/late). For all analyses, $P < 0.05$ was considered statistically significant. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [17].

Results

Table 1 shows the trends in the distribution of demographic data, including the number of all surgeries and each surgery for ONFH, and the distribution of gender and age. Table 1 shows decrease in the proportion of patients aged 16–39 years ($P < 0.001$), and increase in the proportion of patients aged over 60 years of age ($P < 0.001$). We showed the proportion of all surgery in each period in Fig. 2. The proportion of patients who underwent OT decreased from early to middle and late periods (early, 317/947 (33.5%); middle, 396/1659 (23.9%); and late, 176/1167 (15.1%)); the proportion of patients who underwent Hemi decreased from early to middle and late periods (early, 158/947 (16.7%); middle, 173/1659 (10.4%); and late, 68/1167 (5.8%)) and the proportion of patients who underwent THA significantly increased from early to middle and late periods (early, 443/947 (46.8%), middle 1066/1659 (64.3%); and late 919/1167 (78.7%)). Table 2 displays the distribution of demographic data for OT, Hemi, and THA. By age, no significant trend was seen in the number of patients who underwent OT from early to middle and late periods. The proportion of patients over 60 years of age significantly decreased ($P = 0.035$) over the three time periods; however, the number of cases was small (early, 6; middle, 3; late, 0). For Hemi, there was no significant trend across periods. The proportion of patients over 60 years of age who underwent THA significantly increased from early to middle

Table 1 Trends in the distribution of the surgery for ONFH from 2003 to 2017 as all surgery and demographic data

	Early (2003–2007)	Middle (2008–2012)	Late (2013–2017)	$P^{\#}$
Number of participating facilities	22	29	30	0.333
All of surgical cases (number)	976	1686	1182	1.000
All of surgical cases per facilities	44.4	58.1	39.4	1.000
Sex				
Male	601	1002	671	1.000
Female	375	684	511	1.000
Age (years)				
16–39	358 (36.6)	534 (31.7)	314 (26.6)	$P < 0.001$*
40–59	440 (45.1)	716 (42.4)	512 (43.3)	0.449
≥ 60	178 (18.3)	436 (25.9)	356 (30.1)	$P < 0.001$*
Mean age ± SD	45.3 ± 14.7	47.7 ± 15.0	49.0 ± 15.0	0.333

Values are expressed as numbers, parentheses indicate %

Jonckheere-Terpstra test

The Cochran-Armitage test

*A significant difference

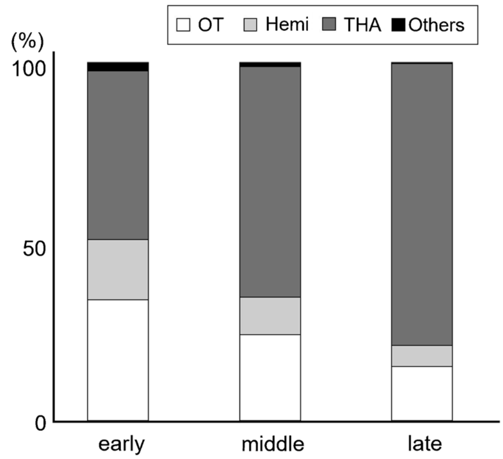

Fig. 2 Proportion of each operation. The study period is divided into early (2003–2007), middle (2008–2012), and late (2013–2017) periods

and late periods ($P = 0.0038$). In addition, we examined whether the proportion of patients who underwent OT decreased, and THA increased over time even for young patients who are likely to be indicated for OT. As a result, the proportion of young patients who underwent OT at 16–39 years of age decreased, and THA increases from early to middle and late periods (eFig. 2).

Regarding the type of classification, for type B, the trend did not change significantly (Fig. 3a). The proportion of patients with types C1 and C2 who underwent OT and Hemi decreased from early to middle and late periods, and the proportion of patients who underwent THA significantly increased over time (Fig. 3b, c) (Table 3).

Regarding the stage, no significant difference was seen in the proportion of patients who underwent OT and Hemi at stages 1 and 2 of ONFH over the three time periods (Fig. 4a). For stages 3A, 3B, and 4 (Fig. 4c, c and d), the proportion of patients who underwent OT and Hemi decreased from 2003 to 2017, and the proportion of THA increased over the three time periods in all stages (Table 3).

Table 2 Distribution of the surgery for ONFH from 2003 to 2017 as osteotomy, hemiarthroplasty, and THA for sex and age

	Early (2003–2007)	Middle (2008–2012)	Late (2013–2017)	$P^{\#}$
The number of the patients underwent OT	314	393	174	1.000
Sex				
Male	227	271	110	1.000
Female	87	122	64	1.000
Age(years)				
16–39	179(57.0)	254(61.6)	103(59.2)	0.384
40–59	129(41.1)	136(34.6)	71(40.8)	0.660
≥ 60	6(1.9)	3(0.8)	0(0)	0.035*
The number of the patients underwent Hemi	157	174	66	1.000
Sex				
Male	90	103	34	1.000
Female	67	71	32	1.000
Age(years)				
16–39	46(29.3)	36(20.7)	16(24.3)	0.219
40–59	69(43.9)	86(49.4)	34(51.3)	0.241
≥ 60	42(26.8)	52(29.9)	16(24.3)	0.902
The number of patients underwent THA	438	1062	917	1.000
Sex				
Male	237	591	516	1.000
Female	201	471	401	1.000
Age(years)				
16–39	107(24.5)	228(21.5)	195 (21.3)	0.246
40–59	209(47.7)	466(43.9)	388(42.3)	0.115
≥ 60	122(27.9)	368(34.6)	334(36.4)	0.004*

Values are expressed as numbers, parentheses indicate %

We counted duplicates in surgical contests separately

[#] Jonckheere-Terpstra test/the Cochran-Armitage test

*A significant difference

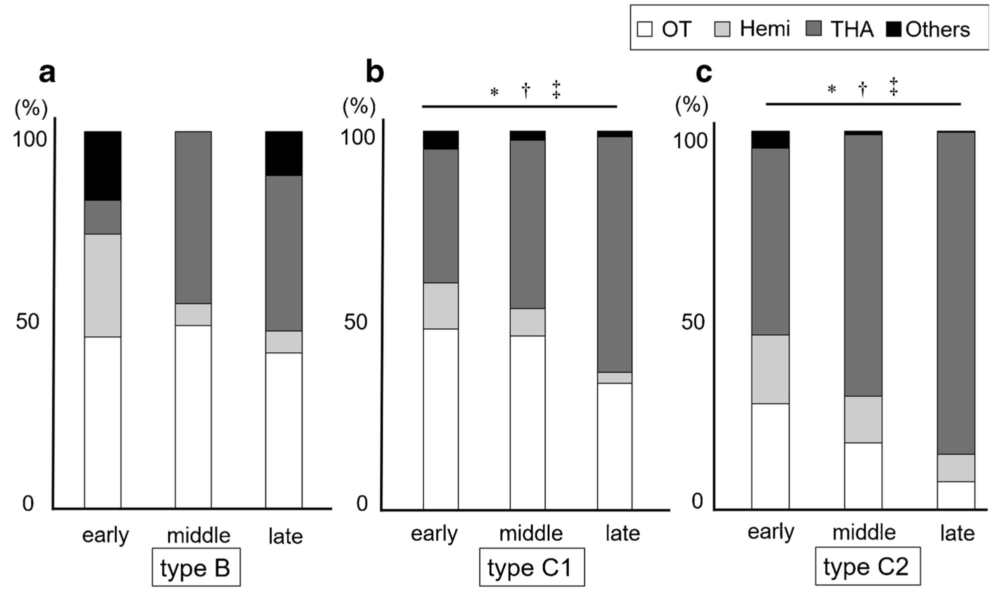

Fig. 3 Proportion of each operation with respect to the type of ONFH. The study period is divided into early (2003–2007), middle (2008–2012), and late (2013–2017) periods.* There is a significant difference in the proportion of patients who underwent osteotomy (OT) from 2003 to 2017. Data are analyzed using the Cochran-Armitage test. † There is a significant difference in the proportion of patients who underwent hemiarthroplasty (Hemi) from 2003 to 2017. Data are analyzed using the Cochran-Armitage test. ‡ There is a significant difference in the proportion of patients who underwent total hip arthroplasty (THA) from 2003 to 2017. Data are analyzed using the Cochran-Armitage test. **a** The proportion of each operation in patients with type B lesions is shown. **b** The proportion of each operation in patients with type C1 lesions is shown. **c** The proportion of each operation in patients with type C2 lesions is shown

In the additional analysis, which included data from 20 facilities that regularly reported patients throughout the study period, the results were unchanged in comparison with the primary analyses. The proportion of patients who underwent OT and Hemi decreased, and that of patients who underwent THA significantly increased over time (eFig. 3). For both types C1 and C2, the proportion of OT and Hemi decreased, and the proportion of THA significantly increased over time (eFig. 4). At stages 3A and 3B, the proportion of OT and Hemi decreased, and the proportion of THA significantly increased over time (eFig. 5).

Discussion

To the best of our knowledge, this was the first study to track the trend in the type of surgical procedures with respect to age, type of lesion, and stage of ONFH.

For all surgical cases, the proportion of young patients decreased, and that of older patients significantly increased from 2003 to 2017. In a previous report, authors reported a shift in the age at diagnosis from younger to older patients from 1997 to 2011 [9]. The authors suggested that the progress in the development of immunosuppressants affected the incidence of steroid-induced ONFH, and this led to the observed shift in age.

The proportion of patients who underwent OT and Hemi decreased, while that of THA significantly increased over time. First, the number of young patients, who often underwent OT for ONFH, decreased during this study period. This may have resulted in a decreased proportion of patients who underwent OT in the current study. Second, early return to daily life and work is preferred today. Hospitalization for OT is longer than that for THA. The average hospitalization duration was about 50 days for patients who underwent OT [18]; such a long period of treatment might not be favoured. Third, the indication of Hemi has been limited according to the recent literatures. For Hemi for ONFH, despite the fact that some studies reported good clinical outcomes and survival rates over a ten year follow-up [19], the number and proportion of Hemi has been decreasing. A retrospective study reported that the patients who underwent Hemi had groin pain, and the revision rate was high [20]. Degradation of the cartilage of the acetabulum was found in a patient who underwent Hemi [21]. For these reasons, Hemi may not have been preferred to THA in the current study. However, at some facilities in Japan, Hemi is believed to be an option for treating ONFH with some surgical indications, such as Ficat stage II or III, and have been performed. As this study was based on registration data, we did not have the details or the decision on the type of surgery depends on each facility.

Good clinical outcomes and joint survival rates of OT have been reported in numerous studies [3, 4, 11–13]. Joint-preserving procedures may be more advantageous for younger patients than for older patients because they have a greater capacity for bone remodeling [13]. However, in our study,

Table 3 Distribution of the surgery for ONFH from 2003 to 2017 as osteotomy, hemiarthroplasty, and THA for type and stage

	Early (2003–2007)	Middle (2008–2012)	Late (2013–2017)	$P^{\#}$
Type				
The number of the patients diagnosed type B	15	37	15	1.000
Osteotomy	8(53.3)	18(48.6)	7(46.7)	0.770
Hemiarthroplasty	5(33.3)	2(5.4)	1(6.7)	0.094
THA	1(6.7)	17(45.9)	7(46.7)	0.144
Others	1(6.7)	0(0)	0(0)	0.765
The number of the patients diagnosed type C1	272	363	322	1.000
Osteotomy	130(47.8)	167(46.0)	108(33.5)	< 0.001*
Hemiarthroplasty	33(12.1)	26(7.2)	9(2.8)	< 0.001*
THA	96(35.3)	161(44.4)	200(62.1)	< 0.001*
Others	13(4.8)	9(2.5)	5(1.6)	0.019*
The number of the patients diagnosed type C2	635	1169	780	1.000
Osteotomy	177(27.9)	205(17.5)	57(7.3)	< 0.001*
Hemiarthroplasty	116(18.3)	144(12.3)	56(7.2)	< 0.001*
THA	313(49.3)	809(69.2)	665(85.3)	< 0.001*
Others	29(4.6)	11(0.9)	2(0.3)	< 0.001*
Stage				
The number of the patients diagnosed stage 1/2	101	103	65	1.000
Osteotomy	52(51.5)	47(45.6)	25(38.4)	0.100
Hemiarthroplasty	9(8.9)	6(5.9)	6(9.2)	0.956
THA	23(22.8)	47(45.6)	30(46.2)	< 0.001*
Others	17(16.8)	3(2.9)	4(6.2)	< 0.001*
The number of the patients diagnosed stage 3A	268	413	350	1.000
Osteotomy	134(50.0)	182(44.1)	110(31.4)	< 0.001*
Hemiarthroplasty	66(24.6)	75(18.2)	25(7.1)	< 0.001*
THA	56(20.9)	146(35.4)	213(60.9)	< 0.001*
Others	12(4.5)	10(2.4)	2(0.6)	< 0.001*
The number of the patients diagnosed stage 3B	289	427	366	1.000
Osteotomy	88(30.4)	107(25.1)	35(9.6)	< 0.001*
Hemiarthroplasty	71(24.6)	77(18.0)	33(9.0)	< 0.001*
THA	122(42.2)	238(55.7)	297(81.1)	< 0.001*
Others	8(2.8)	5(1.2)	1(0.3)	< 0.001*
The number of the patients diagnosed stage 4	215	555	365	1.000
Osteotomy	14(6.5)	24(4.3)	5(1.4)	0.001*
Hemiarthroplasty	7(3.3)	5(0.9)	1(0.3)	0.002*
THA	192(89.3)	524(94.4)	359(98.3)	< 0.001*
Others	2(0.9)	2(0.4)	0(0)	0.071

Values are expressed as numbers, parentheses indicate %

We counted duplicates in surgical contests separately

Jonckheere-Terpstra test/the Cochran-Armitage test

*A significant difference

the proportion of patients who underwent OT decreased over time. In a study conducted by Rijnen et al., only 27% of patients who underwent OT obtained successful results [22]. Additionally, several papers demonstrated that the results of

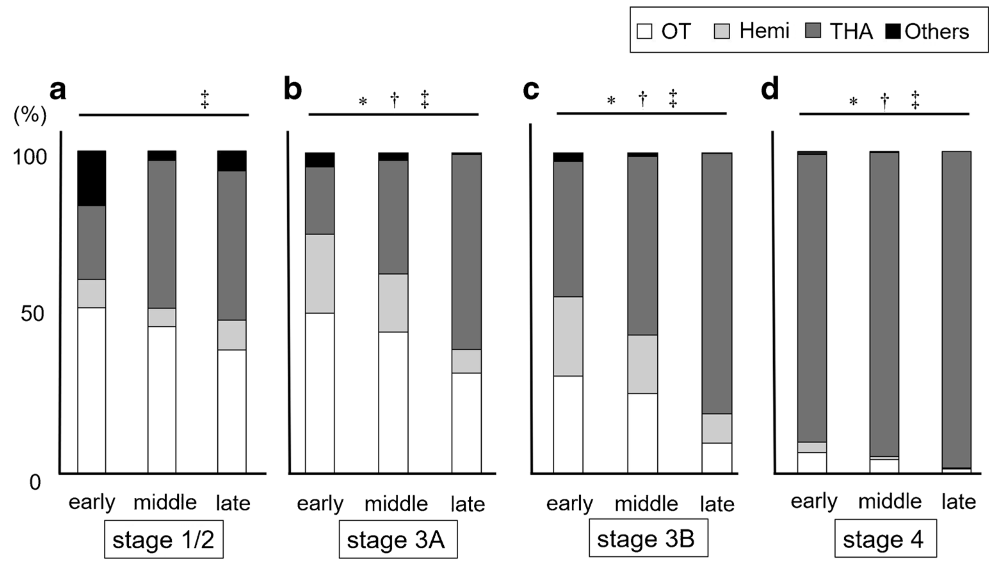

Fig. 4 Proportion of each operation with respect to the stage of ONFH. The study period is divided into early (2003–2007), middle (2008–2012), and late (2013–2017) periods. * There is a significant difference in the proportion of patients who underwent osteotomy (OT) from 2003 to 2017. Data are analyzed using the Cochran-Armitage test. † There is a significant difference in the proportion of patients who underwent hemiarthroplasty (Hemi) from 2003 to 2017. Data are analyzed using the Cochran-Armitage test. ‡ There is a significant difference in the proportion of patients who underwent total hip arthroplasty (THA) from 2003 to 2017. Data are analyzed using the Cochran-Armitage test. **a** The proportion of each operation in stages 1 and 2 is shown. **b** The proportion of each operation in stage 3A is shown. **c** The proportion of each operation in stage 3B is shown. **d** The proportion of each operation in stage 4 is shown

THA after failed OT were worse than those of THA without previous OT [23–25]. We presume that these evidences influence the decision-making among surgeons and patients. Further, the number of surgeons who are able to perform OT has decreased. Therefore, OT is more challenging and requires more skills and experience than THA.

Several retrospective studies have reported the relationship between clinical outcomes and the type and stage of ONFH. One study reported that a post-operative intact ratio of 33.0% is necessary for a satisfactory outcome after transtrochanteric curved varus osteotomy [3]. Another study reported that a post-operative intact ratio of ≥ 36.8% is necessary for the progression of collapse and/or joint space narrowing after posterior rotational osteotomy [8]. A previous study reported that patients who underwent transtrochanteric rotational osteotomy with C2 had a higher risk of conversion to THA than did patients with type B or C1 [7]. In our study, the number of patients with types C1 and C2 who underwent OT decreased over time, and this decrease was more commonly observed in patients with type C2. Therefore, OT is more commonly performed on patients with small necrotic lesions, such as type B lesions, than on patients with types C1 and C2.

A previous study reported that the pre-operative stages of osteonecrosis correlated with the incidence of post-operative osteoarthritic changes. In this report, OT was performed pre-collapse, and those performed post-collapse could not obtain good outcomes [26]. Interestingly, the proportion of THA increased even in stages 1 and 2, when no arthropathy change occurred. Uesugi et al. found that patients with ONFH felt moderate pain even in stages 1 and 2 [27]. Recently, a retrospective study demonstrated good clinical outcomes of the cementless THA for ONFH. They reported that the ten year implant survival rates in both were over 97% [28]. Good performance of THA may have the extended indication to earlier stage of ONFH. The number of cases undergoing OT might decrease. However, we do not believe that it will be eliminated. Owing to the possibilities of implant dislocation and expiration, it is desirable to avoid THA in extremely young patients. It is reported that long-term results of THA performed in patients younger than 30 years are not favourable. Studies have reported polyethylene liner wear and implant loosening [29] [30]. OT is optimal in the case of accurate diagnosis, indications, and surgical technique. For OT, it is important to accurately identify the area of necrosis of the femoral head. Based on the necrotic site, the surgeon should select an operation technique that increases the post-operative intact ratio. In actual surgery, a post-operative intact ratio over a certain value should be obtained [3, 8, 31].

It is important to create an environment that they can introduce the patients who need OT, not THA, to the facilities where the surgeons can perform OT at the appropriate time. In order to have such a system, it will be necessary to collect cases, establish a learning center, and provide appropriate medical care for rare diseases. Simultaneously, it would be crucial to teach the technique of OT. Hence, we are currently trying to establish a learning center [32]. Because advanced surgical technique is required to perform the osteotomy, the facilities where surgeons can perform osteotomies are limited.

Surgical education for OT technique is more difficult than that for THA [32]. Therefore, trainees are taught at major facilities where surgeons regularly perform osteotomies. In addition, some facilities provide educational cadaver programs.

In the recent years, new treatment modalities, such as cell therapy have been performed. Other treatment options include pharmacologic agents and biophysical treatments. Pharmacologic agents include lipid lowering agents, anticoagulants, vasoactive substances, and bisphosphonates. Lipid lowering agents, such as statins, have been shown to provide protective effects for patients receiving steroids. However, it is still unclear whether lipid-lowering agents can reverse steroid-induced ONFH [33]. Anticoagulants, such as enoxaparin, increase blood flow to ischemic areas of the femoral head [34]. Vasoactive substances, such as prostacyclin, improve the blood flow, thus improving the clinical and radiographic outcomes [35]. The long-term benefits have yet to be clear. Bisphosphonates have been shown to reduce the incidence of the collapse of the femoral head. Evidence for prevention of THA and reduction of ONFH progression still remains controversial. Biophysical treatments include extracorporeal shockwave therapy (ESWT). ESWT has been shown to improve pain, function, and size of the necrotic lesion. Although conservative treatment may cause pain and decreased functional outcomes, more studies are warranted to determine the effectiveness of these modalities [36].

Cell therapy can be expected in the future. However, approaches that include specialized equipment and reagents required for cell extraction and purification are still expensive and complex. Hernigou et al. in 2002 described a technique for injecting mesenchymal stem cells into an area of necrosis [37]. Yasunaga et al. described the efficacy of bone marrow mononuclear cells [38]. Sakai et al. described a technique for the concentration of bone marrow aspirate for osteogenic repair [39]. As the osteonecrotic femoral head of patients has fewer osteogenic progenitor cells and poor vascularization, bone regeneration can be expected after transplantation of bone marrow that contains multipotent cells. If these problems including expensive equipment and complex procedure are solved, treatments incorporating cell-based therapy will have potential, based on the hypothesis that ONFH has a cellular origin.

There were several limitations of this study. First, we used a multi-centre hospital-based sentinel monitoring system, which may have resulted in selection bias. The participating facilities in this system were university hospitals and highly specialized hospitals. As a result, patients with more severe conditions may have been selected, and it may be possible to perform a highly difficult surgery there, but otherwise it may not be such a difficult surgery. Second, the surgery that was performed depends on the facility itself. This also might have introduced a selection bias.

In conclusion, in Japan, the proportion of patients who underwent OT for ONFH decreased over time and that of THA increased. The proportion of younger patients decreased and that of older patients increased significantly.

Acknowledgments We thank all the medical doctors for participating in the current survey despite their busy schedules in medical practice, education, and research.

Funding information This study was supported by a research grant from the Research Committee on Osteonecrosis of the Femoral Head of the Ministry of Health, Labour and Welfare of Japan.

Compliance with ethical standards

The study protocol was approved by the ethics committees of each participating hospital.

Conflict of interest The authors declare that they have no conflict of interest. W. Fukushima received payment for lectures on epidemiology at an annual scientific meeting of the Japanese Orthopaedic Association and review article for osteonecrosis of the femoral head.

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