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The impact of the reverse prosthesis on revision shoulder arthroplasty: analysis of a high-volume shoulder practice

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Background: Since the approval of reverse shoulder arthroplasty (RSA) in 2004, the use of shoulder arthroplasty increased dramatically. Although the success of RSA in the revision setting has been demonstrated, there remains a paucity of studies examining the epidemiology of RSA in revision arthroplasty. This study describes trends of revision arthroplasty during the "era of the reverse," from 2005 through 2016.
Methods: In a multicenter retrospective analysis, we analyzed 274 revision shoulder arthroplasties converted to a RSA (n = 182), anatomic total shoulder arthroplasty (TSA, n = 68), or hemiarthroplasty (n = 24) from 2005 to 2016. Demographics, surgical indications, and types of prosthesis were analyzed.
Results: The number of revision arthroplasties increased over 12 years. From 2005 to 2010, TSA (33%) or hemiarthroplasty (16%) were used in similar rates as RSA (51%). From 2011 to 2016, there was a much higher incidence of revision arthroplasty with RSA (78%) compared with TSA (19%) or hemiarthroplasty (3%). Specifically, the number of RSAs increased in 2011 to 2016 compared with 2005 to 2010 in patients aged younger than 60 years, obese patients, patients with indications of glenoid loosening, and those with a diagnosis of diabetes mellitus or rheumatoid arthritis.
Conclusions: The use of RSA for revision arthroplasty increased over the "era of the reverse" and became the majority by 2016. The reverse prosthesis has had expanding indications regarding both patient demographics and pathology. This study demonstrates the reverse prosthesis has had a similar and even more profound effect on revision shoulder arthroplasty than what has previously been well documented in the primary setting.
Level of evidence: Descriptive Epidemiology Study

Keywords: Revision; reverse shoulder arthroplasty; incidence; anatomic; hemiarthroplasty; total shoulder arthroplasty

The Massachusetts General Hospital Institutional Review Board approved this study (IRB Protocol # 2017P002713).

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With the increasing success of the reverse shoulder arthroplasty (RSA) for pathologies other than rotator cuff tear arthropathy, the indications and rates for RSA continue to expand.[6,18,38] A study by Day et al[6] in 2010 predicted that use of reverse arthroplasty would increase from 2007 to 2015 by between 192% and 322%. This is particularly relevant in the revision setting. With the continuously increasing number of hemiarthroplasties and exponentially increasing number of reverse and anatomic total shoulder arthroplasties (TSAs),[18] the number of failures and revision operations will continue to rise. The reverse prosthesis is arguably better suited for the challenges in revision arthroplasty, including glenoid or humeral bone loss and rotator cuff or soft tissue insufficiency, due to its semiconstrained nature and medialized center of rotation compared with the native shoulder.

In the primary setting, 42% of all shoulder arthroplasties performed in the United States (US) were RSAs in 2011.[14] However, there is a paucity of information on the use of the RSA in the revision setting or on the cumulative epidemiologic trends over the "era of the reverse" in revision arthroplasty in the US. Therefore, the purpose of this study was to describe our trends of revision arthroplasty during the time period the reverse was available in the US from 2005 through 2016. Our hypothesis was that the anatomic or hemiarthroplasty were the predominant prostheses used from 2005 to 2010, whereas the reverse prosthesis has been overwhelmingly the predominant implant from 2011 to 2016.

Materials and methods

We performed a multicenter retrospective analysis of the trends in revision shoulder arthroplasty for 2 high-volume, fellowship-trained shoulder surgeons from January 1, 2005, through December 31, 2016. Patients were included if they underwent a revision shoulder arthroplasty to a hemiarthroplasty, anatomic total shoulder arthroplasty (TSA), or reverse shoulder arthroplasty (RSA).

The primary outcome measure in this study focused on the ultimate procedure performed as a result of the failed arthroplasty and the trends over the 12-year study period. Additional factors considered included demographics, indication for the primary and revision arthroplasty, and type of prosthesis used in the primary arthroplasty procedure. We defined study period as the time frame the RSA has been available in the US, from 2005 to 2016, as the 2 surgeons began using the reverse prosthesis early in 2005 after US Food and Drug Administration approval in 2004. We focused on 2 high-volume surgeons because their practices represent a large referral practice devoted almost exclusively to shoulder surgery, with revision arthroplasties representing a sizeable portion of the referrals. Descriptive statistics were used to describe the epidemiologic trends over the study period of the revision arthroplasties.

Statistical analysis was performed using descriptive statistics, including percentages and counts for categorical and ordinal data and means with interquartile ranges for continuous data. We used the Fisher exact test to compare implants used in various time periods. Statistical significance was set at $P < .05$.

Results

Trends in revision shoulder arthroplasties

The number of revision shoulder arthroplasties slowly increased over the 12-year period. The breakdown of the revision arthroplasties performed each year is presented in Fig. 1. The total number of revision arthroplasties performed also increased during this period, from 117 revisions from 2005 through 2010 to 157 revisions from 2011 through 2016. The average duration between the primary and secondary procedure from 2005 to 2010 was 20 months (range, 0-140 months). For the period of 2011 to 2016, the average duration between the procedures was 40 months (range, 0-184 months), with no significant difference between the 2 periods ($P = .5$). There was also no significant difference between the primary diagnoses (osteoarthritis, rotator cuff insufficiency, fracture, avascular necrosis, instability, or other) for the 2 periods.

The period from 2005 to 2010 had an equal amount of revision hemiarthroplasties (n = 19) and TSAs (n = 38) compared with RSAs (n = 60; Table I). At the beginning of the 12-year period, in 2005 through 2006, there were the highest respective percentage of revision arthroplasties performed involving hemiarthroplasties (n = 7) or TSAs (n = 11) compared with RSAs (n = 10). This is in sharp contrast to the most recent 2 years (2015 through 2016), where were 55 RSAs in the revision setting there compared with only 4 TSAs ($P < .01$; Table II). When the first 6 years (2005 to 2010) were compared with the most recent 6 years (2011 to 2016) of the "reverse era," a dramatic increase occurred in the number of revision arthroplasties involving the reverse component, increasing from 51% in the first 6 years to 78% over the most recent 6 years ($P < .01$; Fig. 2).

The increased use of the reverse prosthesis in the revision setting began to exponentially increase from 2013 through 2016 (Fig. 1, Table II). From 2007 to 2012, there was consistently a higher number of revision RSAs (n = 76) compared with revision TSAs (n = 44) or hemiarthroplasties (n = 16). A sharp increase in the number of RSAs occurred in 2013, with a dramatic difference in revision operations performed using the RSA (n = 96) compared with TSAs (n = 13) or hemiarthroplasties (n = 1) from 2013 to 2016. The years 2015 and 2016 had the highest overall percentage of revisions RSAs (93%; $P < .01$).

Trends according to demographics and indications

There were also changes in the demographics and indications for the various components used in revision arthroplasty over the time period (Fig. 3). RSAs comprised 28% of total revisions in patients aged younger than 60 from 2005 to 2010 compared with 55% from 2011 to 2016. In addition, the percentage of reverse prosthesis operations performed in obese (body mass index ≥30 kg/m^2) patients increased from 53% from 2005 to 2010 to 80% from 2011 to 2016 ($P < .01$). Indications for revision surgery showed glenoid loosening comprised 15%

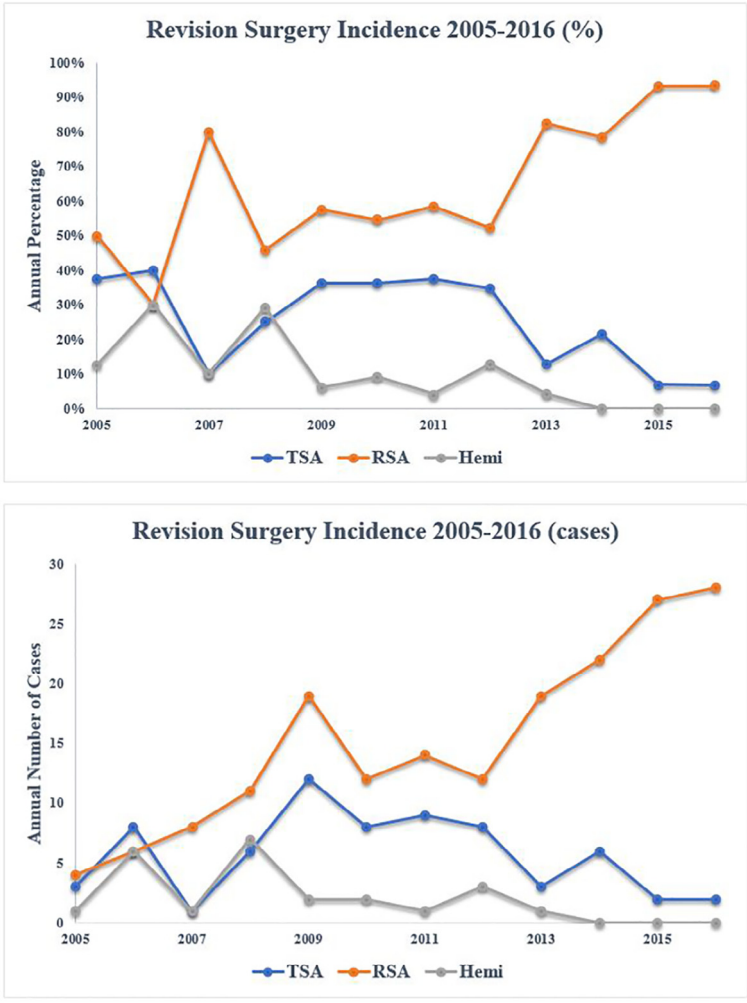

Figure 1 Trends in revision shoulder arthroplasty from 2005 to 2016, in the "era of the reverse." The number of reverse arthroplasties (*RSAs*) dramatically increased during the study period, while the number of hemiarthroplasties (*Hemi*) and, particularly, anatomic total shoulder arthroplasties (*TSA*) decreased in the revision setting.

Table I Revision arthroplasties performed from 2005 to 2010

Procedure	2005 (No.)	2006 (No.)	2007 (No.)	2008 (No.)	2009 (No.)	2010 (No.)	Total (No.)
RSA	4	6	8	11	19	12	60
TSA	3	8	1	6	12	8	38
Hemi	1	6	1	7	2	2	19
Total	8	20	10	24	33	22	117

RSA, reverse shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *Hemi*, hemiarthroplasty.

Table II Revision arthroplasties performed from 2011 to 2016

Procedure	2011 (No.)	2012 (No.)	2013 (No.)	2014 (No.)	2015 (No.)	2016 (No.)	Total (No.)
RSA	14	12	19	22	27	28	122
TSA	9	8	3	6	2	2	30
Hemi	1	3	1	0	0	0	5
Total	24	23	23	28	29	30	157

RSA, reverse shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *Hemi*, hemiarthroplasty.

of all revisions from 2005 to 2010 compared with 36% from 2011 to 2016 ($P < .01$). When 2005 to 2010 was compared with 2011 to 2016, the percentage of those with glenoid loosening revised with RSA increased from 17% to 86%, respectively ($P < .01$). There were also increases in the percentage of RSAs performed between the 2 periods for patients with rheumatoid arthritis (59% to 88%) or diabetes mellitus (65% to 100%). In sex analysis, the percentage of RSAs performed between 2005 to 2010 and 2011 to 2016 increased in both men (41% to 71%) and women (60% to 84%), respectively.

Discussion

Since its first description by Paul Grammont in 1993, the "inverted" or more recently "reverse" shoulder prosthesis has

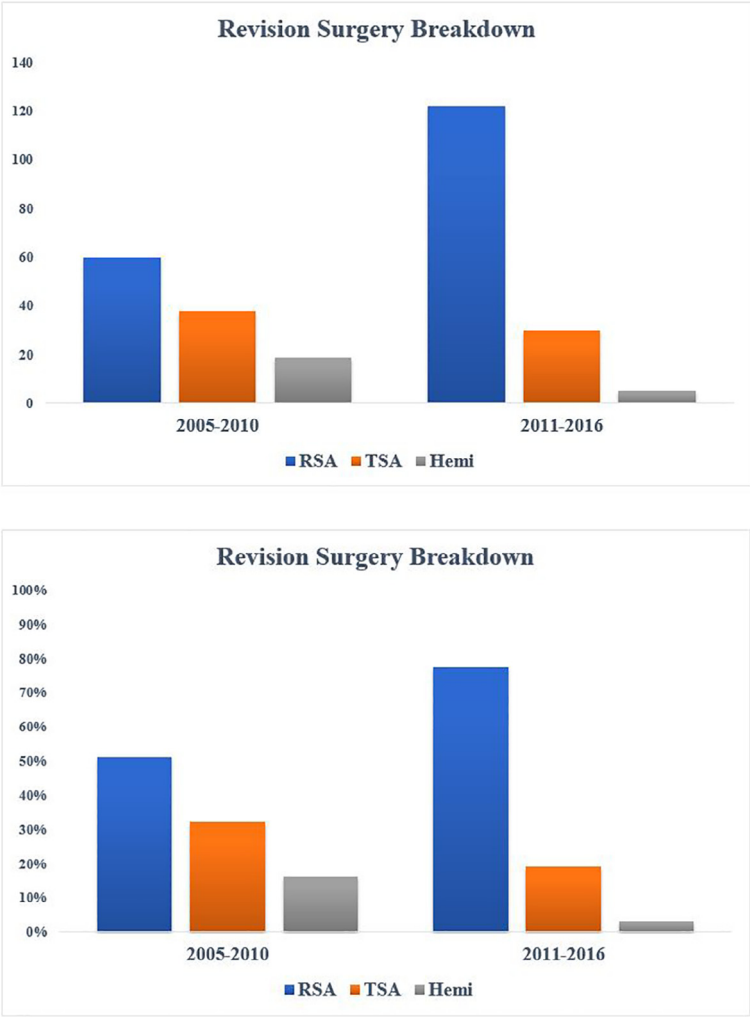

Figure 2 Comparison of the first (2005-2010) and most recent 6 years (2011-2016). There was a dramatic increase in the percentage of revision arthroplasties involving the reverse component, increasing from 51% in the first 6 years to 78% over the most recent 6 years. *RSA*, reverse shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *Hemi*, hemiarthroplasty.

had tremendous success in many situations where TSAs or hemiarthroplasties were prone to poor outcomes.[13] Its use has been gradually expanding during the last 25 years and has been successfully used to treat rotator cuff arthropathy,[4,10,21,30] massive irreparable rotator cuff tears,[4,26,37] inflammatory arthritis,[11,12] instability,[20] glenoid bone loss,[8,23,32] acute fractures,[1,7,9,29] post-traumatic reconstruction,[29,36] and humeral bone loss.[5,19,27]

The approval of the reverse prosthesis in the US in late 2004, beginning with the investigational device exemption study, marked a critical turning point in the treatment of many of these pathologies throughout the country. The following years saw an exponential increase in the use of the reverse prosthesis throughout the US.[6,15,18,38] Although RSA has revolutionized revision shoulder arthroplasty during the last decade,[2,3,16,22,24,25,33-35] there remains a paucity of studies examining the epidemiology of revision shoulder arthroplasty in the "era of the reverse." Therefore, the purpose of this investigation was to examine the trends in revision shoulder arthroplasty since the approval of the reverse prosthesis by the US Food and Drug Administration.

This study confirms the exponentially increasing popularity of the reverse prosthesis, trending what has been observed in the primary setting.[6,15,18,28,38] During the 12-year period, the percentage of revision shoulder arthroplasties increased from 51% in the first 6 years to 78% in the most recent 6 years. The most striking increases happened from 2013 and beyond. In addition, potentially as a result of the success of the reverse prosthesis in treating difficult pathologies faced in the revision setting, the total number of revision shoulder arthroplasties also increased during the study period.

An interesting finding of this study was the increase in the number of revision procedures performed in 2014, with RSA comprising a large percentage (79%) of them. Given the high volume and more than 15 years of experience by both surgeons before 2005, this study demonstrates the effect the reverse prosthesis has had on revision shoulder arthroplasty within the US.

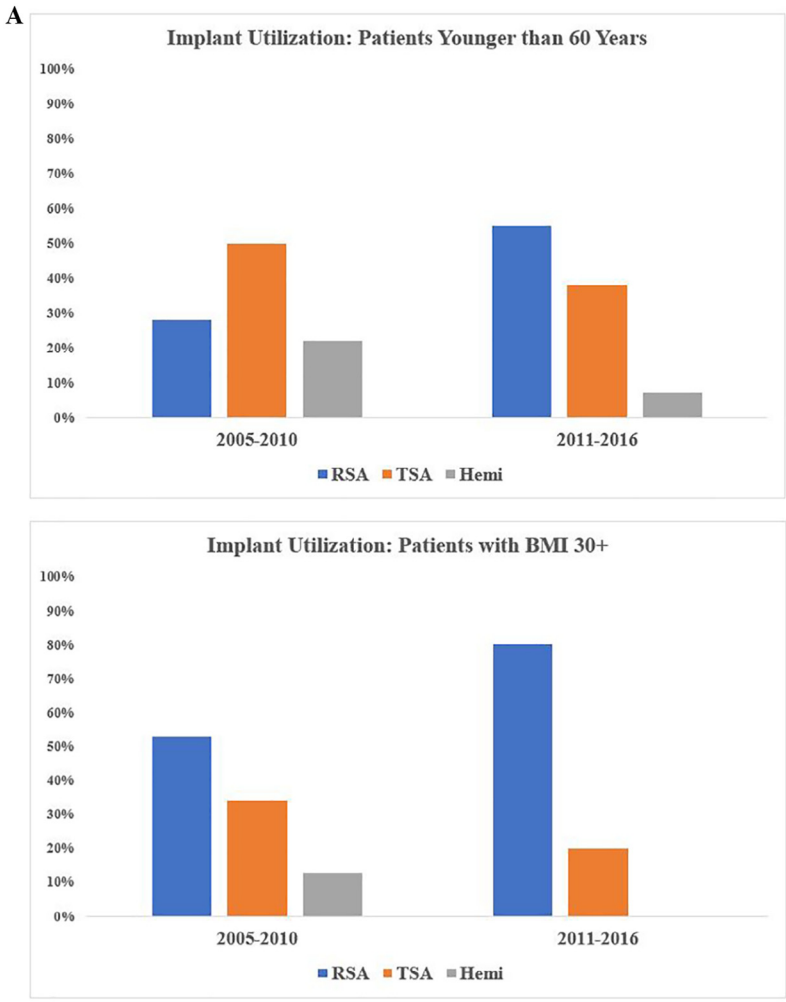

Figure 3 The implant use according to demographics and indication. The number of reverse shoulder arthroplasties (*RSA*) used in the revision setting increased between 2005 to 2010 and 2011 to 2016 for patients (**A**) aged younger than 60 years (28% to 55%), obese patients (53% to 80%), (**B**) indications of glenoid loosening (17% to 86%), (**C**) diabetes mellitus (65% to 100%), (**D**) rheumatoid arthritis (*RA*, 59% to 88%), and in (**E**) men (41% to 71%) and women (60% to 84%). *BMI*, body mass index; *TSA*, total shoulder arthroplasty; *Hemi*, hemiarthroplasty.

Multiple studies have examined the epidemiology of primary shoulder arthroplasty over similar time periods.[6,15,18,38] Day et al[6] used the Nationwide Inpatient Sample (NIS) database to examine the prevalence of TSAs from 1993 to 2007. They demonstrated an annual increase of between 6% and 13%, with a sudden increase toward the end of the study period corresponding to the approval of the reverse prosthesis. The authors projected use rates would increase between 192% and 322% by from 2007 to 2015, a rate that eclipses hip and knee arthroplasty. Kim et al[18] also saw this discontinuous jump in 2004 and exponential increase in use from 2004 to 2008, compared with a steady increase from 1993 to 2003, attributed to the reverse prosthesis.

In a follow-up to both of these studies using the same NIS database, Jain et al[15] found the use of primary shoulder arthroplasty significantly increased from 2009 (n = 52,397) to 2011 (n = 67,184), with the reverse accounting for 42% of all primary shoulder arthroplasties performed in 2011. It should be noted that 2011 was the first year that reverse and anatomic TSA were able to be distinguished from one another in the NIS database due to a lack of the International Classification Of Diseases, Ninth Edition code. Our study demonstrates a similar rise, although the sharp increase in usage rates happened slightly later in 2013. In the year 2011, 58% of revision shoulder arthroplasties involved the reverse prosthesis compared with the 42% demonstrated by Jain et al[15] in the primary setting.

An interesting finding of this study was the increased use of the reverse prosthesis in young patients (<60 years), obese patients, those with an indication of glenoid loosening, patients with rheumatoid arthritis, and patients with diabetes mellitus. In an NIS database study from 2009 to 2011, rotator cuff pathology was the predominant indication for RSA, and older women (range, 75-84 years) had the highest rate of RSA use.[15] The most striking increase involved revisions for glenoid loosening. Although only 17% of patients were revised for

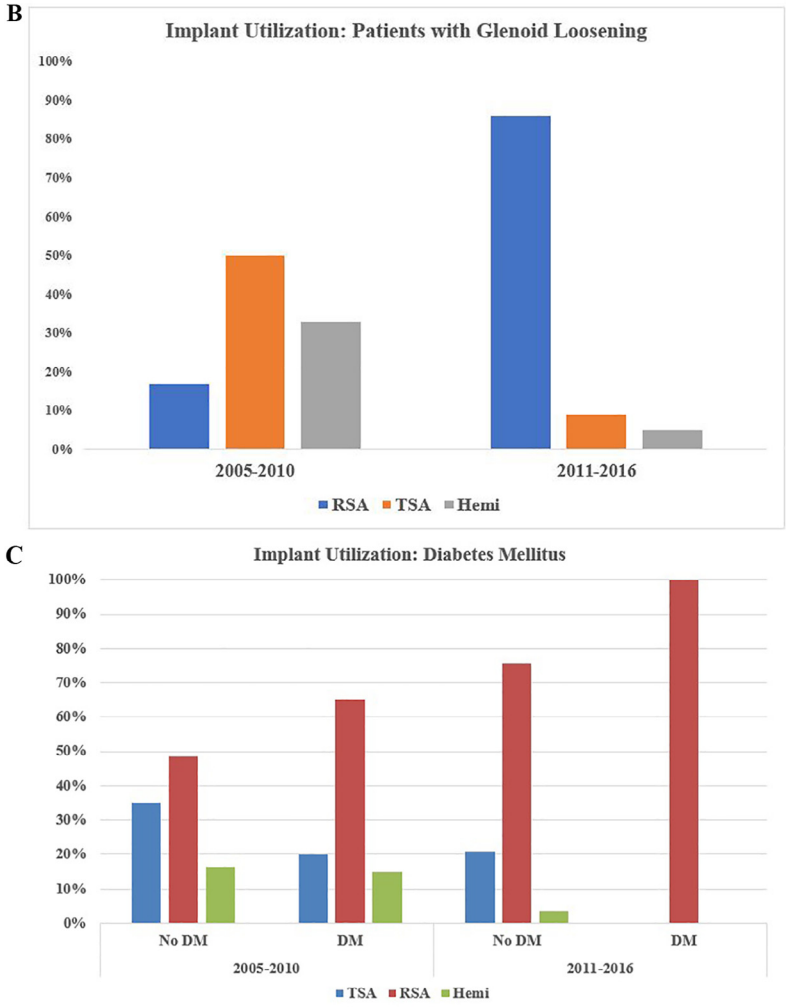

Figure 3 (*Continued*)

glenoid loosening with a RSA from 2005 to 2010 in our study, this number increased to 86% from 2011 to 2016. The increasing use of RSA in the revision setting for glenoid loosening, as well as in younger and obese patients, indicates the surgeons' increasing confidence in the ability of RSA to overcome complex pathologies (ie, glenoid bone loss, diabetes mellitus, rheumatoid arthritis), withstand large loads and high demands through the shoulder (ie, obese, young patients), and its potentially increasing longevity (ie, young patients).

As innovations in surgical techniques evolve, our understanding of disease progression improves, and implant technology continue to develop, it will likely continue to promote an increase in the use of shoulder arthroplasty to treat a variety of shoulder pathologies. The reverse prosthesis will likely continue to be largely responsible for this rise, as the last decade has seen it develop from a "salvage operation" to one that rivals anatomic TSA in most outcomes, including pain relief, function, motion, reoperations, and complications.[17,31] This increasing use of shoulder arthroplasty will be accompanied by a gradual increase in the need for revision surgery of those implants that fail. The reverse prosthesis is likely to continue to be the dominant implant in the revision setting, in a large part due to its ability to compensate for soft tissue and bony deficiencies encountered in the revision setting via its semiconstrained articulation, medialized center of rotation, and glenoid ingrowth and compression capabilities.

The results of this study should be taken into account only when considering its limitations. It is limited to 2 surgeons and, therefore, is not representative of a nationwide sample. We purposely limited it to 2 high-volume shoulder surgeons at 2 tertiary referral centers to specifically analyze the effect the reverse prosthesis has had on the practices of surgeons who perform a high number of revision procedures. Nonetheless, these results cannot be generalized to surgeons whose practices consist of a lower volume of revision procedures. An analysis of the outcomes of these procedures is beyond the scope of this study, thus limiting our ability to comment on the success of the reverse prosthesis over the study period or when compared with TSA or hemiarthroplasty.

Finally, given this multicenter study is based at 2 tertiary referral centers, the study is subject to a referral bias.

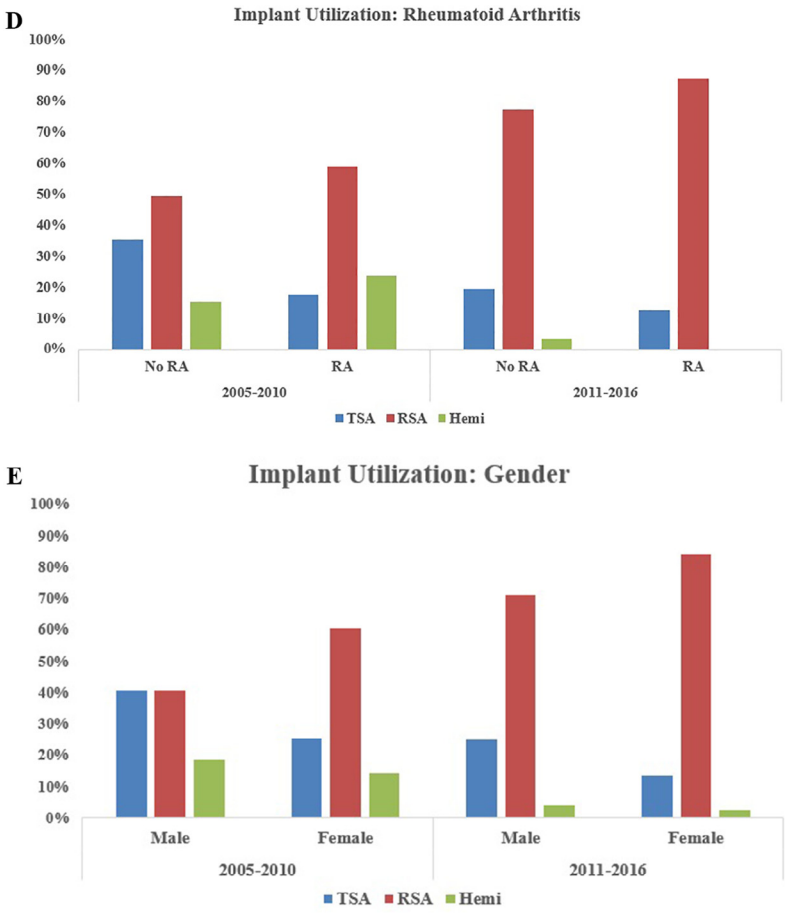

Figure 3 (*Continued*)

Conclusions

The use of the reverse prosthesis in the revision setting increased over the "era of the reverse" from 2005 to 2016. A gradual, continuous increase occurred from 2005 to 2012, followed by a sharp, discontinuous increase in 2013, and was followed by exponential increases in use rates over the following years. In 2015 and 2016, 93% of all revisions performed by 2 high-volume shoulder surgeons at 2 tertiary referral centers involved the reverse prosthesis compared with only 36% a decade earlier (2005 and 2006). The reverse prosthesis has had expanding indications regarding both patient demographics and pathology. This study demonstrates the reverse prosthesis has had a similar and even more profound effect on revision shoulder arthroplasty than what has previously been well documented in the primary setting.

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