



# Long-term results of the uncemented resurfacing shoulder hemiarthroplasty (Global Conservative Anatomic Prosthesis)

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**Background:** Treatment with uncemented resurfacing shoulder hemiarthroplasty has proved to be viable for patients with end-stage osteoarthritis at short- and mid-term follow-up. This study was essential to determine whether those outcomes will endure. This study presents the long-term results of the Global Conservative Anatomic Prosthesis (CAP) uncemented resurfacing shoulder hemiarthroplasty (DePuy Synthes, Warsaw, IN, USA).

**Methods:** All patients with a diagnosis of glenohumeral osteoarthritis and an intact and clinically sufficient rotator cuff who underwent uncemented resurfacing shoulder hemiarthroplasty between 2007 and 2009 were included. The data of all patients who completed the 10-year follow-up assessments were used for analysis. The visual analog scale pain score, Dutch version of the Simple Shoulder Test score, Constant score, Short Form 12 scores, and physical examination findings were evaluated preoperatively and postoperatively on an annual basis. All complications and revisions were documented. Radiographs were evaluated for loosening, luxation or subluxation, migration, and glenoid erosion.

**Results:** Of 48 shoulders, 23 (48%, 18 women and 5 men) were available for the 10-year follow-up assessments and their data were used for analysis. The main reasons for dropout were revision (27%) and death (10%). The mean follow-up period of the remaining patients was 10.9 years (range, 9–13 years). The visual analog scale pain score (from  $6.5 \pm 2.1$  to  $0.7 \pm 1.6$ ,  $P < .001$ ), Simple Shoulder Test (Dutch version) score (from  $22\% \pm 22\%$  to  $79\% \pm 22\%$ ,  $P < .001$ ), Constant score (from  $40 \pm 29$  to  $70 \pm 8$ ,  $P < .001$ ), and Short Form 12 physical score (from  $36 \pm 7$  to  $41 \pm 12$ ,  $P = .001$ ) improved significantly compared with preoperative scores. Revision surgery was performed in 13 of the initial 48 shoulders (27%). Most revisions were seen within 7 years postoperatively.

**Conclusion:** Two revisions have been performed in the mid-term to long term because of increased functional outcome scores and the absence of signs of loosening. Nevertheless, the high overall revision rate of 27% between short- and long-term follow-up reflects the need to limit the use of uncemented resurfacing shoulder hemiarthroplasty for the treatment of glenohumeral osteoarthritis.

**Level of evidence:** Level IV; Case Series; Treatment Study

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**Keywords:** Shoulder; osteoarthritis; cementless; resurfacing; arthroplasty; glenoid; lateralization

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To decrease pain and restore function to the osteoarthritic shoulder, total shoulder replacement arthroplasty is an acknowledged procedure.<sup>12,14,21,40,42</sup> Nevertheless, over time, there is a need for revision surgery, which is a result of glenoid component loosening in up to 39% of revisions.<sup>4,7,8,16,45</sup> An alternative to total shoulder replacement arthroplasty is hemiarthroplasty, which eliminates glenoid component complications.<sup>27,39</sup> However, in the long term, hemiarthroplasty may lead to progressive glenoid erosion and arthritis with subsequent pain development and loss of range of motion.

Among hemiarthroplasty prostheses, the resurfacing shoulder prosthesis has the major advantage that the humeral component does not need a stem or cement for fixation.<sup>29,41</sup> Additional benefits include minimal bone resection and a short operative time; moreover, revision surgery is a relatively accessible procedure causing minimal bone loss.<sup>9,10,28,30,32,33</sup> Without the use of a stem, complications such as intraoperative humeral shaft and postoperative periprosthetic fractures can be limited.<sup>28,46</sup> In terms of fixation success, complications such as aseptic loosening are common.

The Global Conservative Anatomic Prosthesis (CAP) uncemented resurfacing shoulder hemiarthroplasty (DePuy Synthes, Warsaw, IN, USA) has a cruciate-shaped stem and has a hydroxyapatite-coated porous surface, which enables primary fixation. Short-term results showed that this arthroplasty is comparable to stemmed hemiarthroplasty and resurfacing arthroplasty.<sup>18</sup> Mid-term results showed a concerning revision rate of 23%, which is in line with other studies.<sup>17,23</sup> Long-term follow-up is essential to determine whether the uncemented resurfacing hemiarthroplasty is a viable option for patients with end-stage osteoarthritis of the shoulder. To date, no study has been published with long-term results of the Global CAP.

The purpose of this study was to evaluate the long-term functional and radiologic outcomes and revision rates of the Global CAP uncemented resurfacing shoulder hemiarthroplasty. We hypothesized that patients would show acceptable clinical outcomes but that the overall revision rate would be too high to recommend this implant as the first line of treatment in primary shoulder osteoarthritis.

## Materials and methods

### Study design

This study was performed as a prolongation of a follow-up study in patients treated with the uncemented Global CAP resurfacing shoulder hemiarthroplasty. Short-term results were published in 2014,<sup>18</sup> and mid-term results were published in 2017.<sup>17</sup> Informed consent was obtained from all participants.

### Participants

All patients aged >18 years with primary glenohumeral osteoarthritis treated with the global CAP resurfacing hemiarthroplasty between January 2007 and December 2009 were eligible for participation. The inclusion criteria were patients with (1) failed conservative treatment; (2) an intact and clinically sufficient rotator cuff; (3) minimal 60% bone stock of the proximal humerus (estimated on radiographs and magnetic resonance imaging [MRI] in 2 directions); and (4) centric glenoid wear of type A1, A2, or B1 according to the Walch classification assessed on MRI.<sup>44</sup> The exclusion criteria were patients with rotator cuff tears >1 cm assessed on MRI (even if patients had a clinically intact cuff, they were excluded if, on MRI or intraoperatively, the cuff tear was >1 cm). For all shoulders, preoperative radiographs and MRI scans were obtained.

### Intervention

All surgical procedures were performed by the senior authors (A.v.N. and C.P.J.V.) in 2 clinics: Alrijne Hospital (Leiderdorp, The Netherlands) and Spaarne Gasthuis (Hoofddorp, The Netherlands). All patients were treated with the Global CAP uncemented resurfacing shoulder hemiarthroplasty. Thirty minutes before the first incision, 1 g of cefazolin was administered intravenously. General anesthesia in combination with a preoperative interscalene block was used. All patients were placed in the beach-chair position with the arm draped free. The deltopectoral approach was used in all shoulders. The pectoralis major tendon and the vessels of the humeral circumflex artery were preserved. At approximately 1 cm medial to its insertion, the subscapularis tendon was divided. The soft tissue of the anterior and inferior aspects of the capsule and all around the subscapularis tendon was released if necessary to improve range of motion. The subscapularis tendon was left attached with the anterior aspect of the capsule to increase suture fixation of the tendon back to its original fixation on the minor tubercle. Patients with a diagnosis of tendinopathy (27%) intraoperatively received tenodesis (21%) or tenotomy (6%) of the long head of the biceps. Lateral clavicular resection was performed in patients with symptomatic acromioclavicular joint arthritis (15%). The most suitable size of implant was placed with respect to anatomic retroversion and inclination. The Chondro Pick (Smith & Nephew, Memphis, TN, USA) was used for microfracturing of the damaged articular surface of the glenoid to stimulate the growth of fibrous cartilage in 94% of all treated patients (n = 45). No glenoid implants were used.

### Rehabilitation

For the first 6 weeks after surgery, all patients used a standard sling. Patients were stimulated to perform front-to-back pendulum exercises and passively and actively assisted forward elevation and abduction movements. External rotation was allowed to the maximum degree obtained preoperatively during the first 6 weeks to minimize the tension on the reattached subscapularis tendon. All patients followed a rehabilitation protocol consisting of supervised physiotherapy for 3-6 months and self exercises.

## Clinical assessment

The baseline assessments were performed in the outpatient clinic by 1 of the senior authors (C.P.J.V. or A.v.N.). Baseline characteristics were recorded, and radiographs and MRI scans were obtained. Patient assessment included the visual analog scale (VAS) for pain,<sup>38</sup> patients' activities of daily living (Short Form 12 [SF-12]),<sup>15,24</sup> the Dutch version of the Simple Shoulder Test (DSST),<sup>25</sup> and shoulder function including range of motion and strength, which was also used for the Constant score.<sup>11,26</sup> The 10-year follow-up patient assessments were performed by a physician assistant (P.S.) and the first author (A.L.v.G.), who did not participate in the perioperative care. For revision surgery, the decision was based on shared decision making with our patients and involved use of the VAS score and range of motion in combination with glenoid erosion on radiographs.

## Radiologic assessment

Anteroposterior and axillary radiographs of all shoulders were obtained on the first day postoperatively and at 3 months, as well as subsequently every year that followed. Signs of loosening were recorded by evaluating the presence of radiolucent lines and their evolution over time. Definite loosening was defined as a change in position of a component over time. Probable loosening was defined as progressive radiolucencies >2 mm at the component-bone interface with an unchanged position. Loss of joint space was defined as a decrease in the distance between the hemiarthroplasty and the glenoid, expressed in millimeters. The rate and severity of humeral migration in relation to the glenoid, as well as the presence of luxation or subluxation, were recorded. Glenohumeral luxations or subluxations to caudal and posterior were assessed on anteroposterior radiographs. We evaluated translation of the center of the prosthetic head to the center of the glenoid; this was graded as none (0%), mild translation (<25%), moderate translation (25%-50%), or severe translation (>50%). Medialization was defined as medial movement of the center of rotation with regard to the lateral acromion. Severe medialization was defined if the distance between the center of rotation and the lateral acromion was >10 mm. Cranialization was defined as a decrease in the acromiohumeral distance. Comparison was made to the first postoperative radiographs.

## Statistical analysis

Descriptive statistics were used to present patient characteristics including sex, age at the time of surgery, and age at the time of 10-year follow-up. Normal distribution was examined by visually examining histograms. Normally distributed variables were described using the mean and standard deviation. Non-normally distributed variables were described using the median and lower and upper limits of the interquartile range. Patients were considered available for analysis if the 10-year follow-up assessments had been completed. We used linear mixed models or the Friedman test to analyze preoperative Constant scores, shoulder function including internal and external rotation and strength, VAS scores, SF-12 scores, and DSST scores, as well as these scores at 2, 5, and 10 years of follow-up.  $P < .05$  was considered

statistically significant. All data were analyzed using SPSS software (version 26.0; IBM, Armonk, NY, USA).

## Results

### Participants

A total of 46 patients with 48 resurfacing hemiarthroplasty operations (2 bilateral) met the inclusion criteria and were included in the follow-up study. Twenty-two patients (17 women and 5 men) with 23 resurfacing hemiarthroplasty operations (48%) (1 bilateral) were available for the 10-year follow-up assessments, and their data were used for analysis in this study. The reasons for loss of follow-up were revision operations (13), death (5), health-related issues (2), withdrawal of informed consent (2), unattainable contact (2), and emigration (1). The mean age at the time of surgery was  $64.6 \pm 6.7$  years. The mean age at the time of 10-year follow-up analysis was  $76.6 \pm 6.7$  years. The mean follow-up duration was 10.9 years (range, 9-13 years).

### Clinical assessment

The VAS pain score significantly decreased from  $6.5 \pm 2.1$  preoperatively to  $0.7 \pm 1.6$  at 10-year follow-up. The mean SF-12 physical score significantly improved from  $36 \pm 7$  preoperatively to  $41 \pm 12$  at 10-year follow-up ( $P = .001$ ). The mean SF-12 mental score decreased from  $52 \pm 10$  preoperatively to  $49 \pm 12$  at 10-year follow-up ( $P = .464$ ). The mean DSST score significantly improved from  $22\% \pm 22\%$  preoperatively to  $79\% \pm 22\%$  at 10-year follow-up ( $P < .001$ ). The corrected mean Constant score significantly improved from  $61 \pm 29$  preoperatively to  $97 \pm 8$  at 10-year follow-up ( $P < .001$ ). The preoperative scores and short-term (2-years of follow-up), mid-term (5-years of follow-up), and long-term (10-years of follow-up) scores are presented in [Table I](#).

### Radiologic assessment

Radiographs were available for 23 shoulders in 22 patients. Of the shoulders, 1 (4%) showed minimal signs of loosening. No luxation or subluxation of the hemiarthroplasty was seen. In 16 shoulders (70%), no change in the position of the arthroplasty was observed over time. Medialization was seen in 7 shoulders (30%); 3 of these shoulders (13%) showed severe medialization. In 4 shoulders (17%), cranialization was seen. Erosion of the glenoid was present in 17 shoulders (74%) at long-term follow-up. In 12 shoulders (52%), loss of joint space between the glenoid and the arthroplasty was detectable. In 4 shoulders (17%), the joint space was still clearly visible. The results of the radiologic assessment are summarized in [Table II](#).

**Table I** Preoperative and postoperative scores (n = 23)

Score	Mean				P value
	Preoperative	Short term (2 yr)	Mid-term (5 yr)	Long term (10 yr)	
Constant score	40	70	73	75	<.001
Sex- and age-adjusted Constant score	61	78	94	97	<.001
DSST score, %	22	74	72	79	<.001
VAS score	65	27	24	7	<.001
SF-12 score					
Physical	36	45	37	41	.001
Mental	52	51	51	49	.464

DSST, Dutch version of Simple Shoulder Test; VAS, visual analog scale; SF-12, Short Form 12.

**Table II** Radiologic assessment (n = 23)

Radiological findings	n (%)
Loosening	1 (4)
Glenohumeral luxation or subluxation	0 (0)
Change of position	
None	16 (70)
Medialization	7 (30)
Severe medialization	3 (13)
Humeral cranialization	4 (17)
Glenoid erosion	17 (74)
Lucencies	
Not detectable	12 (52)
Clearly visible	4 (17)

## Complications

The reported perioperative complications were described in the publication presenting the short-term results.<sup>18</sup> There were no major complications (malposition of the implant, neurovascular damage, infection, or humeral fracture). Three minor complications occurred, for which a second surgical procedure was needed. One subscapularis rupture underwent reattachment. One fractured osteophyte from the posterior rim of the glenoid was removed. One lesser tuberosity avulsion fracture, which occurred after intensive exercise, underwent reattachment.

## Revision surgery

In the course of the short-term follow-up, no revision surgery was performed or necessary.<sup>18</sup> After 5-8 years of follow-up, 11 patients (23%) underwent revision surgery. Between the mid-term and 10-year follow-up, 2 patients underwent revision. Of the initial 48 shoulders, in total 13 (27%) underwent revision within 10 years postoperatively (Table III). During the revision operations, the resurfacing implant was removed and revised to a total shoulder arthroplasty (62%) or a reverse shoulder arthroplasty

(38%).<sup>17</sup> The mean age of patients with conversion to reverse shoulder arthroplasty was 72 years at the time of revision surgery. These patients had proven rotator cuff arthropathy. The reasons for revision surgical procedures were glenoid erosion (46%), pain in combination with poor function (38%), low-grade infection (8%), and anterior subluxation (8%).<sup>20</sup>

Kaplan-Meier survival analysis was performed to estimate the survivorship of the Global CAP (Fig. 1). The 10-year survival rate of the implant was 67%.

## Discussion

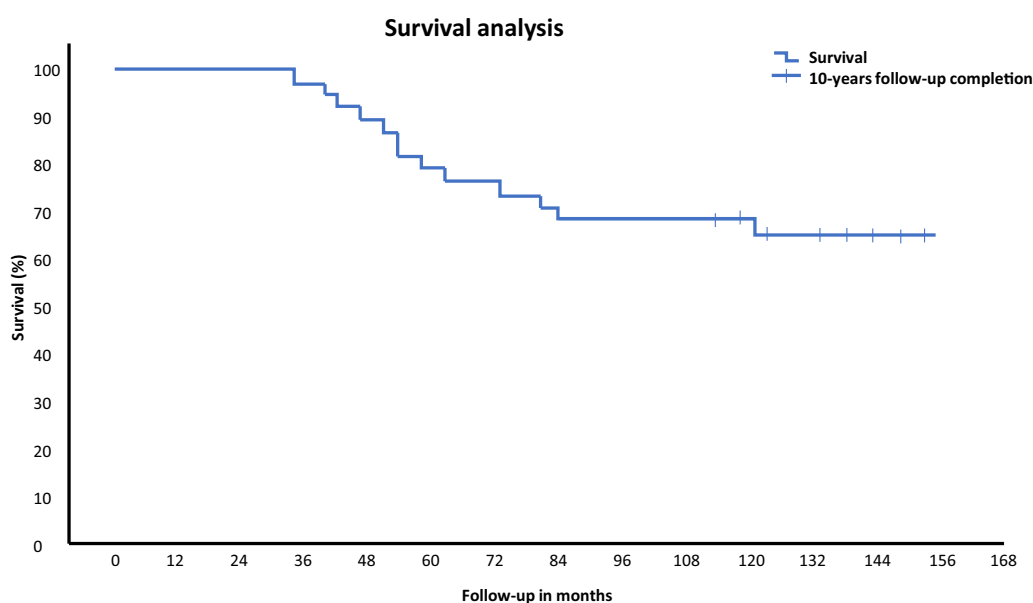
In this study, the most important results of the Global CAP shoulder resurfacing hemiarthroplasty were the reduction of pain and the increased physical capabilities after 10 years of follow-up. Most revisions were seen within 7 years postoperatively. The overall revision rate increased slightly in the long term.

The functional outcome scores (VAS, Constant, DSST, and SF-12) are comparable with the results of other resurfacing shoulder arthroplasty procedures.<sup>13,30,36</sup> In our study, all of the clinical outcome scores improved over the years, except for the SF-12 mental score. All patients experienced a reduction in pain, reflected by an average VAS score of 6.6 preoperatively vs. a VAS score of 0.7 after 10 years of follow-up. Regarding physical capabilities, all patients showed an increase in functionality, represented by a mean Constant score of 39 preoperatively vs. 75 after 10 years of follow-up. Dekker et al<sup>13</sup> presented the results of Copeland resurfacing hemiarthroplasty of the shoulder, with a Constant score of 49.9 postoperatively. Levy et al<sup>30</sup> described surface replacement arthroplasty in patients aged <50 years. The mean Constant score of the younger patients increased from 10.5 to 62. An exception to the improving results was the SF-12 mental score, which remained unaffected over a 10-year period. The SF-12 mental score of 49 in our study is similar to the SF-12 mental score of 49.8 after 12 years of follow-up of the Copeland Mark III

**Table III** Revision surgery (n = 13)

Patient no.	Follow-up prior to revision, mo	Reason	Revision procedure
1	34	Pain	TSA
2	40	Low-grade infection and persistent pain	TSA
3	42	Arthrofibrosis, poor function, and pain	TSA
4	47	Severe glenoid erosion and progressive pain	TSA
5	51	Cuff arthropathy, glenoid erosion, poor function, and pain	RSA
6	54	Poor function and progressive pain	TSA
7	54	Anterior subluxation	RSA
8	58	Poor function and pain	TSA
9	63	Severe glenoid erosion, loss of range of motion, and progressive pain	RSA
10	73	Glenoid erosion and progressive pain	TSA
11	81	Glenoid erosion and progressive pain	TSA
12	84	Rheumatoid arthritis and progressive pain	RSA
13	122	Glenoid erosion	RSA

TSA, total shoulder arthroplasty; RSA, reverse shoulder arthroplasty.



**Figure 1** Kaplan-Meier survival curve with revision surgery as endpoint.

system.<sup>36</sup> Despite patients experiencing an increase in functionality and decrease in pain, patients do not benefit thereof in terms of mental health aspects.

The relative increase in functional outcome scores is a remarkable finding. All patients with poor functional outcome scores had undergone revision and, therefore, were not included in our analyses. Nevertheless, the mean scores improved over the years. Normally, in the aging patient, the Constant scores decreases,<sup>47</sup> whereas in our group, the overall scores increased. This finding suggests that the Global CAP continues to work well in the long term, under the conditions that the patient functions well after a hemiarthroplasty and there are no reasons for revision surgery.

In the radiologic assessment, after 10-year follow-up, no abnormalities leading to revision have been seen. The cases with radiologic glenoid erosion were revised in a preliminary stage.<sup>20</sup> One case presented a mismatch between functional capabilities and radiologic outcomes: The radiograph of the shoulder of this patient shows progressive erosion of the glenoid with exceptional medialization of the humeral head (Fig. 2). Nevertheless, this patient is satisfied with the Global CAP according to consultations in the outpatient clinic. Other studies have similarly shown that radiologic glenoid deterioration does not necessarily coincide with pain or functional limitations.<sup>3,31,34</sup>

For revision surgery of resurfacing hemiarthroplasty, the most frequent reason is erosion of the glenoid. In our study,



**Figure 2** Right shoulder with progressive glenoid erosion and medialization of humeral head 10 years after resurfacing hemiarthroplasty (Global CAP). R, right.

46% of the revisions were due to glenoid erosion. This finding is in line with the findings of Verstraelen et al,<sup>43</sup> who observed erosion of the glenoid in 45.5% of patients after Copeland Mark III arthroplasty. Herschel et al<sup>22</sup> described risk factors for glenoid erosion in patients with shoulder hemiarthroplasty. They found that a valgus position of the prosthetic head of  $>50^\circ$  in relation to the glenoid led to local destruction of the cartilage.

Previous research has shown a wide range of revision rates for resurfacing prostheses. The revision rates range from 3% to 27% after follow-up periods of 3-22 years, with an increasing trend over the last several years.<sup>1,2,35,37</sup> Levy and Copeland<sup>28</sup> reported a revision rate of 7.7% at long-term follow-up for the Copeland Mark II prosthesis. Among younger patients, Levy et al<sup>30</sup> found a revision rate of 14% after 10 years' follow-up. Geervliet et al<sup>17</sup> found a 23% revision rate after 5-8 years' follow-up. In line with the trend, we observed a revision rate of 27%. In general, from a surgeon's point of view, the ease of revision surgery in resurfacing hemiarthroplasty cases could be a reason for the higher revision rates. Nevertheless, the patient will only be motivated to undergo additional surgery in case of intolerable complaints. After revision of failed resurfacing hemiarthroplasty, mid-term clinical and patient-reported outcome measures have satisfactory results.<sup>20</sup> Van den Bekerom et al<sup>6</sup> compared hemiarthroplasty with total shoulder arthroplasty in a systematic review. They found a

greater decrease in pain, improved range of motion, and diminished revision rate after total shoulder arthroplasty. However, total shoulder arthroplasty results in more complications. For all options within scope, resurfacing hemiarthroplasty could therefore be used as an intermediate step before total or reverse shoulder arthroplasty for younger patients.

In our study, the 10-year Kaplan-Meier implant survival rate with revision surgery as the endpoint was 67%. A potential risk factor for Global CAP failure is deviation of the center of rotation as found by Geervliet et al.<sup>19</sup> Our survival rate is within the range reported in existing research. It is higher than the 41% survival rate of resurfacing arthroplasty after 5-year follow-up reported by Lebon et al<sup>27</sup> but lower than the 93.5% survival rate reported by Beck et al<sup>5</sup> after 10-year follow-up. The implant survival rate of the Global CAP after 7-year follow-up was 80% according to Ingoe et al.<sup>23</sup>

### Strengths and limitations

To our knowledge, our study is the first to present the 10-year follow-up results of uncemented glenohumeral resurfacing hemiarthroplasty (CAP). There are limitations applicable to this study, which are mostly due to the study design. We have not included a control group treated with other types of hemiarthroplasty or total shoulder arthroplasty. Therefore, the long-term results have been compared with the preoperative results from the sample. Another limitation is that 52% of all initially included patients were unavailable for final follow-up. The main reason was that patients died (10%) or underwent revision surgery (27%). Furthermore, we were not blinded to the study results. Nevertheless, outcome assessment bias was minimized by having assessors in the outpatient clinics who were not involved with the initial operation.

### Conclusion

In line with our hypothesis, we have observed both that patients showed excellent clinical outcomes similar to the short- and mid-term results and that the overall revision rate (27%) was too high for recommendation. We have seen steadily increasing functional outcome scores for patients who still had the Global CAP hemiarthroplasty at 7 years postoperatively. Moreover, from a radiologic point of view, there have been no signs of loosening. This has diminished the need for additional revisions after 10 years. However, owing to the high overall revision rate of 27% after 10 years of follow-up, we do not recommend using the Global CAP as the treatment of choice for glenohumeral osteoarthritis.

## Disclaimer

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Arthur van Noort is a key opinion leader for Johnson and Johnson.

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