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Indications and results of primary and revision total elbow arthroplasty (literature review)

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Indications to primary and revision total elbow arthroplasty, clinical outcomes and implant survival rate depending on underlying pathology are discussed in the literature review. Total elbow arthroplasty (TEA) has become the method of choice for severely comminuted distal humerus fractures, posttraumatic conditions and inflammatory arthropathies. TEA can provide substantial improvement in elbow function and quality of life as seen from the review of the foreign and native Russian literature for the last 10 years. However, the complication rate that requires revision surgery remains rather high, and the reported 10-year survival of elbow implants (83–92 %) is lower than that in total hip and knee replacements. Purpose To identify major indications to primary and revision total elbow arthroplasty and explore mid- and long-term results of the procedures based on the review of the foreign and native Russian literature for the last 10 years.

Keywords: arthroplasty, elbow joint, rheumatoid arthritis, posttraumatic condition, postoperative complications, survival of endoprosthesis

INTRODUCTION

Total elbow arthroplasty (TEA) represents an alternative treatment option for patients with articular destruction secondary to inflammatory arthropathy or as a consequence of trauma providing immediate pain relief with a stable and functional elbow [1–3]. In comminuted distal humerus fractures, there is a role in performing total elbow arthroplasty to aid in the restoration of function and range of motion that can be difficult to achieve with osteosynthesis [4, 5]. Postoperative rehabilitation course of a patient with elbow joint replacement is much shorter compared to that after osteosynthesis. TEA was shown to provide reliable long-term outcomes for elderly patients with modest activity [6]. The reported significant complication rate following TEA is very much higher than the complication rate associated with any other major limb joint replacement. The most frequent complications requiring revision surgery are aseptic loosening, instability, and infection [7].

Indications to primary TEA

The indications for primary TEA include all the diseases that affect the elbow joint: rheumatoid arthritis, inflammatory arthropathies, idiopathic arthrosis, severely comminuted fractures and posttraumatic conditions. There has been a continuing annual increase in the number of patients treated with TEA. Recent series performed in Russia and abroad have reported positive clinical outcomes of TEA. Although the average implant survival rate after TEA is close to that reported with THA and TKA TEA surgery is technically demanding with high complicaton and reoperation rates [8]. Authors investigated national trends and projections for upper extremity arthroplasty and demonstrated a threefold increase in primary TEAs in the United States between 1993 and 2007 through the analysis of the National Inpatient Sample [9]. A fivefold increase in revision TEA was reported during the above time period [10].

Rheumatoid arthritis of the elbow joint

Rheumatoid arthritis is a chronic, systemic, inflammatory disease of unknown etiology that affects connective tissue and characterized by symmetric erosive and destructive multiple joint involvement (Fig. 1). The benefits of conservative treatment of arthritis result in reduced rate of surgical interventions according to the data of the Norwegian Arthroplasty Register and the Scottish Morbidity Record [11, 12]. Nevertheless, disease modifying antirheumatoid drugs (DMARDs) and inhibitors of tumor necrosis factor (TNF) based treatments fail to provide remission of the disease. Intra-articular glucocorticoid injections provide a small and short-term pain-suppressing effect

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but the corticosteroids are known to cause severe deleterious effects on the articular cartilage [13]. If the conservative management does not provide sufficient relief, joint replacement represents a highly effective and relatively safe surgical treatment option for stiff, unstable joints or pathological fractures. Depending on the severity of involvement patients can undergo arthroscopic synovectomy, interpositional arthroplasty or total joint replacement [14].

Fig. 1 Anteroposterior and lateral radiographic views of the elbow joint showing grade III rheumatoid arthritis according to the A.Larsen scoring system with symmetric narrowing of the articular space, periarticular osteoporosis and osseous erosions being characteristic radiological signs of rheumatoid arthritis

Advances in total joint replacement, understanding elbow biomechanics, implant designs, implant survival rate facilitated favorable postoperative functional results and improved the quality of life of patients. The reported significant complication rate following TEA is therefore very much higher than the complication rate associated with any other major limb joint replacement [15]. The 10-year survivorship of 1457 primary TEAs for rheumatoid elbow destruction performed between 1982 and 2006 was 83 % according to the Finnish Arthroplasty Register [16].

T.T. Pham et al. reviewed 46 patients with rheumatoid arthritis treated with TEA. At an average of 7 years of follow-up (2–16 years), excellent and good results were observed in 49 patients, 3 had fair outcomes and 2 had poor results. The survival rate was 85 % at 10 years. There were 14 complications (26 %) observed. Revisions were performed in 7 cases (13 %) [17]. Meta-analysis produced by J. Sanchez-Sotelo et al. included 461 primary Coonrad-Morrey TEA performed in 387 patients, with the median follow-up of 10 years (range, 2 to 30 years). The rate of survivorship free of implant revision or removal for any reason was 92 % at 10 years, 83 % at 15 years and 68 % at 20 years [18].

A.A. Roskidaylo et al. retrospectively reviewed patients with rheumatoid arthritis (lytic form, fibrous and bony ankylosis) treated with TEA and detected substantial improvement of the elbow function and the quality of life at a 12-month follow-up. The mean Oxford elbow score was 20.44 ± 9.06 preoperatively and 39.33 ± 3.11 at a 12-month follow-up [14]. A.B. Slobodsky et al. reported early, mid- and long-term results of the TEA (range, 0.5 to 10 years) in young patients with rheumatoid arthritis. Excellent and good outcomes were observed in 78.8 % of cases, fair and poor outcomes were seen in 15.4 % and 5.8 % of patients, respectively [19]. Therefore, analysis of the Russian and foreign literature shows that TEA allows functional restoration of the elbow joint and improved quality of life of patients with rheumatoid arthritis, however, the complication rate that requires revision surgery at a mid- and long-term follow-up remains rather high, and the reported 10-year survival of elbow implants (83–92 %) is lower than that in total hip and knee replacements.

Idiopathic arthritis

Idiopathic arthritis is a rare indication to TEA and more common in males older than 50 years and less frequently in manual female laborers [20]. Patients present with pain at extreme flexion or extension that result in contracture, with forearm rotation being persistent in the majority of cases. Chondromal bodies can be present in the joint (Fig. 2). Bony proliferation and osteophytes can be observed in the olecranon and coronoid processes. A narrow articular space indicates to the extent of wear and tear of the humeroulnar joint. Pain with the whole arc of motion is a sign of synovitis. Pain experienced at 90 degree extension indicates to evident articular cartilage degeneration that is not common at advanced stages of arthritis [21]. Signs of ulnar neuropathy are observed in 20 % of patients with primary osteoarthritis. Signs and symptoms of neuropathy can be neglected by patients until they develop expressed muscle atrophy. A close relationship of the nerve to the articular capsule makes it susceptible to an injury from osteophytes, synovitis in the medial part of the joint resulting in capsule expansion. Carpal tunnel

syndrome occurs in the patients as a pain in the medial part of the elbow joint and an examination for ulnar neuropathy is required.

There are very few publications in the foreign literature reporting results of TEA in patients with idiopathic arthritis. In 1998 there was a report on 5 patients with idiopathic arthritis treated with Coonrad-Morrey TEA. An average follow-up evaluation of 3 years showed complications in 4 patients, although revision was required in 2 cases [22]. In 2017 E.F. Ibrahim et al. reported the results of TEA in 14 patients (21 elbows) with mean clinical follow-up of 11.7 years. Survivorship was 95 % at 5 years and 68 % at 10 years. Reoperation, including implant revision, was required in 9 elbows (42.9 %) [23]. Thus, literature review shows that idiopathic arthritis is not common among diseases and conditions of the elbow that requires joint replacement. The reported complication rate associated with TEA is high enough.

Fig. 2 Anteroposterior and lateral radiographic views of the elbow joint showing grade III idiopathic deforming arthritis according to the N.S.Kosinskaya scoring system with multiple chondromal bodies seen in the joint

Posttraumatic conditions

Elbow fractures constitute 7 % of all skeletal injuries [24]. Open reduction, internal fixation and early mobilization of the joint is the standard treatment for distal humerus fractures and types B and C (AO/ASIF classification) proximal ulna injuries [25]. Reliable bone reconstruction and stable fixation of fractures can be problematic in elderly patients due to metabolic diseases, poor circulation in the upper limb and diminished bone quality even with angular stable plate fixation [26]. A major complication rate and poor outcomes is reported as high as 20 % [27]. There is a high risk of posttraumatic arthritis with severe pain and joint contracture (Fig. 3).

Fig. 3 Anteroposterior and lateral radiographic views of the elbow joint showing posttraumatic elbow deformity after distal humerus and olecranin fracture; synostosis of radioulnar joint

Surgical options offered to treat arthritis include arthrodesis, interpositional arthroplasty and TEA. Elbow arthrodesis results in substantially impaired function of the upper limb to be used in activities of daily living, personal care and hygiene [28]. Resection arthroplasty cannot provide proper functionality of the upper extremity interfering with joint stability [29]. A complication rate of 42 % is reported in patients with posttraumatic arthrosis with aseptic loosening being the most common cause of revision surgery [30]. Cil A. et al. reviewed 92 patients who underwent TEA for distal humeral nonunion. Reoperation rate was 43 % at an average follow-up of 6.5 years. Revision surgery was mostly caused by aseptic loosening (n = 12) [31]. J.Y. Kho et al. reported the results of TEA in 66 patients with posttraumatic arthritis. Complications developed in 5.3 % of patients at an average follow-up of 105 months [32]. T. Throckmorton et al. reported an overall complication rate of 34 % in patients with posttraumatic arthritis at a 9-year follow-up [33]. A.B. Slobodsky observed an 8 % complication rate in patients with posttraumatic defects of the elbow at a long-term follow-up [34]. V.M. Prokhorenko et al. detected complications in 4.4 % of the patients who underwent TEA for intra-articular fractures and posttraumatic conditions [1]. Review of the Russian and international literature shows confounding complication rates in patients with posttraumatic conditions. The underlying disease treated with arthroplasty is likely to be an important prognostic

factor for the survivorship. An overall reoperation rate ranges from 4 to 43 % at a long-term follow-up with aseptic loosening being the most common cause of revision surgery.

Indications to revision joint replacement

The most recognized complications of primary joint replacement requiring revision surgery include:

- aseptic loosening;
- deep periprosthetic joint infection;
- dissosiated prosthetic components;
- broken prosthetic component;
- periprosthetic fracture.

There is a wide range of current designs for TEA including nonconstrained and constrained elbow prostheses depending on a link between the humeral and the ulnar components. Nonconstrained prosthesis features anatomical design. The constructs are not widely used since they are indicated for patients with maintained static and dynamic stabilizers: osseous constituents of the elbow joint, capsule and collateral ligaments. Constrained constructs are characterized by coupling mechanism of the humeral and the ulnar components in hinge with constrained or semi-constrained attachment and can be used in presence of bone defects and insufficiency of the capsule and the ligaments. Mechanism of loosening is identical for both types of implants and dissociation is a problem of nonconstrained constructs [35].

Aseptic loosening

The complication normally occurs at mid- and long-term follow-up period with the overall rate ranging between 2 % and 17 % [36–37]. The presence of a radiolucent line or focal areas of bone loss (osteolysis) are sometimes described. There are many hypotheses generally used to explain mechanism of aseptic loosening due to polyethylene wear particles, in particular. However, all TJR implants undergo wear of the bearing surfaces, producing particulates and other by-products of the different materials used in the surgical reconstruction. Polyethylene particles are sheared off and are deposited within the joint space. These particles are then engulfed by macrophages that induce osteoclastogenesis and trigger the pathway of bone resorption. It is currently thought that wear particles generated from the polyethylene are the main inducers of the macrophage response that leads to osteolysis. Polyethylene wear particles accumulate in the joint fluid and get incorported at the bone-cement interface generating debris and progression of osteolysis [38]. Polyethylene wear depends on the thickness and structure of the polyethylene and the level of stress applied. The collected reports identify host factors associated with increased rates of aseptic loosening including younger age, male sex and high activity level. Polyethylene wear is shown to be more commom in constrained implants. Early aseptic loosening is often asymptomatic. Clinical symptoms are an indication to revision arthroplasty. Early prophylactic revision can be considered due to progression of bone resorption to prevent a more complicated revision intervention and periprosthetic fracture [39].

E.V. Cheung and S.W. O'Driscoll described implant loosening in patients with impingement between the coronoid process and the anterior flange of the humeral component occurred at maximal elbow flexion. The authors advocated prophylactic removal of the coronoid process after TEA to the attachment level of the brachial muscle [40]. G.J. Puskas et al. reported aseptic loosening that occurred in only 16 (2.3 %) of 711 TEAs during a mean follow-up of 70 months (range, 16–165months). Revision rate was correlated to the surgical diagnosis and was significantly higher for post-traumatic patients than for rheumatoid patients (5.1 % vs 0.66 %). There was no significant difference in the revision rate between different stem lengths [41]. J.C.T. van der Lugt et al. studied standard radiographs of 125 primary Souter-Strathclyde total elbow prostheses using nonconstrained implants. After a mean follow-up period of 5.5 (2–19) years, 21 (17 %) prostheses loosened radiographically. Survivorship was 65 % at 10 years. With the humeral component being tilted more medially or more anteriorly radiolucent lines of osyteolysis were observed with no signs of progression. No significant effect of improper component position on aseptic instability was detected [39]. Aseptic loosening has been reported to be one of the most common causes for revisions, ranging from 2 % to 17 % at a long-term follow-up. Aseptic failure and instability are primarily caused by linear wear of the polyethylene inserts with progressive osteolysis initiated by wear by-products. Other predisposing factors include younger age and high activity level. There was no statistically significant correlation detected between component size and malposition and the development of aseptic loosening.

Deep periprosthetic joint infection(PJI)

The elbow is a superficially located joint with a minimal amount soft tissues around it and signs of inflammation are more apparent. A systematic review estimated that 3 %–8 % of patients undergoing elbow arthroplasties develop a PJI [42]. Risk factors for infection after TEA include rheumatoid arthritis, history of elbow surgery, local infection and anti-TNF therapy [43].

Three diagnostic criteria for PJI discussed at the Second International Joint Conference (SIJC) on Musculoskeletal Infection include presence of a sinus tract communicating with the prosthesis, identical pathogens isolated in two or more samples obtained in sterile conditions and presence of pus in the joint cavity. Non-specific signs and symptoms include swelling in the joint, erythema or warmth around the joint, elevated levels of ESR, C-reactive proteins, WBC count, specifically polymorphonuclear cells in the synovium, and histological signs of acute inflammation [44].

Recommended surgical management of deep PJI in the elbow are debridement, resection arthroplasty, arthrodesis or removal of prosthetic components and new prosthesis implantation. Although resection arthroplasty is a good solution for elderly patients with lower functional demands the patients can be expected to have poor surgical outcomes. Defect of the medial and lateral epicondyles of the humerus can lead to considerable instability with short humerus decreasing muscle strength with resultant flail limb. Elbow arthrodesis is associated with much functional impairment due to lost range of motion, and there is a risk of refracture with physical activities [45].

There is a useful classification scheme for PJI based on the time to infection, classified as early, delayed, or late onset. Early-onset PJI occurs < 3 months after the last surgery. Delayed-onset PJI occurs after 3 months [46]. One-stage revision can be advocated for early onset PJI. Delayed-onset PJI occured after 3 months would require a two-stage operative treatment with antibiotic impregnated spacer to be placed at the first stage (Fig. 4). S.D. Schoifet and B.F. Morrey concluded that one-stage revision could be effective if performed within 30 days after the symptoms except for Staphilococcus epidermitis isolates being known to readily form biofilms, so risk of recurrent infection being very high after one-stage revision [47]. Materials of SIJC suggest that no clear indications have been identified for deep PJI of the elbow joint to be eradicated at one-stage revision surgery, although presence of sinus tract communicating with the prosthesis and/or compromised soft tissues surrounding the joint or systemic sepsis would support use of two-stage revision [44].

Fig. 4 Anteroposterior and lateral radiographic views of the elbow joint showing non-articulating antibiotic impregnated spacer placed at the first stage of revision TEA. The patient developed PJI 2 years after primary TEA

K. Yamaguchi et al. reviewed their experience with the treatment of PJI in 25 patients who were managed with multiple, extensive irrigation and debridement procedures with retention of the original components, two-stage revision and resection arthroplasty. 25 cases of deep PJI after TEA showed *Staphilococcus epidermitis* as the most virulent pathogen [48]. Recurrence of PJI was observed in all cases of one-stage revision with reimplantation of unstable components and two-stage revision the infecting organism of *Staphylococcus epidermidis* (n = 4). None of the patients who underwent a resection arthroplasty had signs of infection at the latest follow-up examination. The authors concluded that one-stage and two-stage revision surgeries in the presence of an infection about the elbow could be reasonably successful if the infecting organism is not *Staphilococcus epidermitis*.

W.B.J. Rudge et al. identified 19 consecutive patients who had revision arthroplasty for deep prosthetic infection. All patients underwent a first-stage procedure with removal of implants, debridement, and insertion of an antibiotic-loaded cement spacer, followed by at least 6 weeks of intravenous antibiotics. Fourteen patients (74 %)

required a second-stage revision due to persistent infection. Eleven of the 14 patients (79 %) undergoing reimplantation of an elbow prosthesis remained infection free and three developed recurrent infection [45]. In 2013 C.A. Peach et al. reported a series of 33 patients who underwent two-stage revision, insertion with an antibiotic-loaded cement spacer and triple injections of cefuroxime was appled as antibacterial therapy (1 intraoperative and 2 postoperative injections). Successful eradication of the infection was noted in 89 % of the cases. Debridement was required in 15 % before reimplantation, and one patient had 4 repeat procedures [49]. C.A. Kwong et al. presented a case of a persistent, late-onset PJI in an older woman with severe refractory rheumatoid arthritis. The offending pathogen, Aspergillus terreus, grew concurrently with coagulase-negative staphylococcus. Two attempts at reimplantation arthroplasty with excision of necrotic tissues failed with multiple courses of antifungal and antibacterial therapy. The patient ultimately required definitive resection arthroplasty. The authors concluded that fungal infection made the treatment more complicated and was likely to reduce success of reimplantation [50].

R.J. Otto et al. reported on five elbow arthrodeses performed after a failed elbow arthroplasty due to deep PJI [51]. No patients had radiologically confirmed union of the humerus and ulna at the latest follow-up. Two patients developed a fibrous union. All patients required at least 1 reoperation. Three patients required revision arthrodesis after hardware failure. Two patients ultimately underwent a resection arthroplasty. The authors suggested that elbow arthrodesis could not be recommended as a salvage procedure for failed TEA after infection because of a high reoperation rate and difficulty in achieving solid fusion.

Literature review shows that deep PJI is the second common cause for revision after aseptic loosening. One-stage revision with retention of prosthetic components can be advocated for early onset PJI (< 3 months). Delayed-onset PJI occured after three months would require a two-stage operative treatment with antibiotic impregnated spacer to be placed at the first stage. Comparative study showed that the isolated infecting organism of Staphylococcus epidermidis resulted in greater recurrence rate of PJI.

Dissociation of the prosthetic components

The complication is normally encountered with use of nonconstrained constructs and the rate of dislocation after TEA ranges between 0 and 15 % at a long-term follow-up accounting for about 25 % of the total complication rate described [52]. Dissociation of the prosthetic components can be caused by ligament deficiency around the elbow or malpositioned implant components [53, 54]. Key soft tissue structures include the collateral ligaments, ventral portion of the joint capsule and triceps. S.W. O'Driscoll et al. suggested that dissociation of components was a common complication after TEA in which unlinked design of prosthesis was used. Instability after TEA could be due to bone and soft tissue defects, incorrect component selection or position and use of medial approach associated with injury to the medial collateral ligament [55]. If dislocation occurs due to soft tissue deficiency it can be addressed with closed reduction followed by immobilization for 3-6 weeks with the limb flexed at 90 degrees. Revision surgery reimplantation with linked design can be considered for recurrent displocation. Reconstruction of the collateral ligaments can be offered as an alternative to improve stability of the joint. However, D. Ring et al. reported satisfactory functional results without episodes of re-dislocation of unlinked elbow prosthesis only in 3 patients at 6-year follow-up. Nevertheless, the authors opted for at least one attempt of soft tissue reconstruction with less harm involved as compared to revision and reimplantation [54]. The complication is a rare event and more common for unconstrained design of prostheses. Important prognostic factors include preserved bony architecture of the joint, adequate position of prosthetic components and preserved ligamentous structures.

Fractures of the prosthetic components

Fractures of TEA components are uncommon. Meta-analysis made by G.S. Athwal and B.F. Morrey included 919 cases of Coonrad-Morrey TEA. The prevalences of humeral and ulnar component fracture following primary TEA performed were 0.65 % and 1.2 %, respectively [56]. N. Gschwend et al. reported their experience with 828 GSB elbow prosthesis with 0.5 % rate of fractured components due to excessive bone mobilization and incorrect prosthetic position (Fig. 5) [57].

Fig. 5 Anteroposterior and lateral radiographic views of the elbow joint showing broken ulnar component of Coonrad-Morrey TEA due to fatigue fracture and the neglected proximal ulnar defect

Although wear of the articular polyethylene surface may not be a practical concern in unconstrained, unlinked designs, linked implants are subject to bushing wear and disassembly.The „sloppy-hinge" design used with linked implants relies on the integrity of the soft tissue envelope surrounding the elbow joint and allows for 7-10 degrees varus-valgus that can affect wear of the polyethylene on the bushing of the linked prosthesis and varus-valgus amplitude. Polyethylene wear can lead to metal-on-metal contact resulting in a fractrure of one of the hinge components. The mechanism was described in many constrained designs [58].

D.R.J. Gill and B.F. Morrey reported 15 % rate of polyethylene wear in patients with rheumatoid arthritis at a follow-up evaluation of 10 to 15 years [59]. B.P. Lee et al. retrospectively reviewed the results of 919 replacements with the semi-constrained linked Coonrad-Morrey implants and found that twelve patients (1.3 %) had undergone an isolated exchange of the articular bushings as a result of polyethylene wear [60]. W.H. Seitz Jr et al. reported 81 Coonrad-Morrey TEAs with 5 young active patients demonstrating failure of the central locking and bushing components. Three of 5 patients underwent repeat revision due to recurrent hinge mechanism failures. Severe metallosis was intraoperatively observed in the joint. The authors recommended timely detection and replacement of worn polyethylene components in younger patients with a more active lifestyle to prevent early loosening and fracture of the components [61]. Thus, hinge fractures are more common with elbow prosthesis due to substantial wear of polyethylene bushing requiring early revision to preserve remaining bone stock.

Periprosthetic fracture

The prevalence of periprosthetic fractures following elbow arthroplasty has been reported to be 5 % after primary surgery [62, 63]. Intraoperative fractures can occur during canal preparation and during component implantation in elderly patients in association with osteopenia at a short- and long-term follow-up. Nonoperative repair of periprosthetic fractures often results in nonunion that ranges between 20 and 50 % [64]. Y. Yanagisawa et al. described their experience with the treatment of periprosthetic humeral shaft fracture in a woman with rheumatoid arthritis and osteoporosis after TEA using the Ilizarov external fixator that was shown to be a useful option facilitating bone union, a good functional result and mobilization of the elbow joint throughout the treatment [65].

In 2011 A.M. Foruria reviewed 31 consecutive patients with periprosthetic fractures around the ulnar stem. Surgical reconstruction included revision of the ulnar component in all cases. Fracture fixation was achieved with a longer stemmed implant. Strut allografts were used to repair defects of the proximal ulna, with additional impaction graft augmentation. Ulnar component was loose in most of the cases and finally led to a fracture. 78 % of the patients could not exactly tell when the fracture occurred. Peri-implant osteoporosis and osteolysis caused by polymethylmethacrylate cement and polyethylene micropartciles played a role in periprosthetic fracture [66]. There are many reports describing this complication, and periprosthetic fractures are common in elderly patients with poor bone quality. Nonunion is reported to develop in 20–50 % of patients treated with nonoperative techniques. Optimal surgical options include revision arthroplasty, impaction graft augmentation and external ring fixation.

CONCLUSION

Posttraumatic conditions of the elbow joint and rheumatoid arthritis are most common indications to primary TEA. Review of the Russian and international literature shows better implant survival rate and less

complication rate in patients with rheumatoid arthritis. Aseptic loosening and periprosthetic joint infection are reported to be most common complications of primary TEA that require revision. The findings of many international series indicate to the two-stage revision as an optimal treatment of deep PJI. No substatial studies of PJI are available in the Russian literature.

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