The success of total elbow arthroplasty (TEA) is due to improved, reliable implant designs as well as the use of a more sophisticated surgical technique. An increasing amount of evidence exists in support of the correlation between triceps reconstruction and cement technique and better outcomes.1,2 The higher complication rate with TEA compared with arthroplasty of the three other major joints is in part the result of the nature of the patient population. TEA is typically performed in high-risk, previously operated posttraumatic and rheumatoid patients who require treatment with disease-remitting agents.3 Improved outcomes and functionality of the entire upper extremity is demonstrated by the high subjective satisfaction rate of patients who have undergone TEA (>90%)4,5 (Figure 1).

**Indications and Contraindications**

Pain is the most common indication for TEA and is likely the most reliably managed. In the absence of complications, most patients experience pain relief. The elbow is unlike other joints in that a substantial number of patients who present with gross instability, usually following resection arthroplasty for infection or for distal humeral nonunion or distal humeral fracture and nonunion, are well managed with a replacement prosthesis.4 Select patients with ankylosed or frankly fused joints experience marked improvement following TEA.

The contraindications to TEA are similar to those for other joints. Low-grade or subacute infection is the most significant contraindication. Neurogenic dysfunction, particularly lack of elbow flexion, is an absolute contraindication to TEA. However, lack of triceps function is not a contraindication because the elbow can be extended with gravity. Any condition that can be managed effectively with an alternative procedure is a relative contraindication. For example, impingement or stiffness associated with primary degenerative arthritis is a relative contraindication because this presentation is well managed with open or arthroscopic débridement of the joint. Poor quality skin is a relative contraindication that can be addressed with preemptive soft-tissue plastic surgery or intraoperative soft-tissue management. The surgical technique is described and demonstrated in the accompanying video on Orthopaedic Knowledge Online.

**Outcomes**

Several recently developed linked implants are currently in use. However, most reported outcomes are based on unlinked implants or on the linked Coonrad-Morrey device (Zimmer, Warsaw, IN). Four major findings have been documented following TEA with the Coonrad-Morrey device: outcomes vary depending on the underlying diagnosis, outcomes deteriorate over time, stem fixation with placement of a bone graft behind the anterior flange is extremely reliable, and bushing wear occurs with longer follow-up (>10 years is recommended).
Pearls and Pitfalls

**Pearls**
- Avoid complications by anticipating them. Preoperative aspiration should be done to rule out septic processes.\(^2\)
- TEA is contraindicated in the patient who is being actively treated with disease-remitting agents.
- Obtain a plastic surgery consult in the presence of significant soft-tissue compromise and in the patient who is at risk of wound healing problems.
- Establish adequate surgical exposure to enable correct orientation and placement of the implant (Figure 2).
- Linked implants do not require collateral ligaments. Release the collateral ligament to obtain adequate exposure.
- Identify and decompress the ulnar nerve to prevent ulnar nerve–related problems.
- In the patient with rheumatoid arthritis, be mindful of osteoporotic bone to avoid fracture, particularly of the olecranon.
- Cement should be delivered into the canals with an injector system to ensure adequate cement-implant-bone interface.
- Perform meticulous triceps reconstruction. The technique varies depending on the surgical exposure selected (Figure 3).
- Postoperatively, the arm should be immobilized in full extension with an anterior splint. Avoid direct pressure over the wound (Figure 4).
- Remove sclerotic bone with a burr rather than with a rasp.

**Pitfalls**
- Inadequate exposure of the canal may result in improper orientation of the implant.
- Avoid malrotation of either the humeral or the ulnar component (Figure 5).
- Lack of appreciation of an excessively thinned olecranon process or one that is porotic may result in olecranon fracture intraoperatively or postoperatively.
- Lack of attention to persistent drainage may lead to infection.
- Early motion that compromises wound healing should be avoided.
- Inadequate preoperative assessment may result in device implantation in a patient with a low-grade infection.
- Lack of proper patient expectations may result in overuse postoperatively, which may lead to loosening or premature articular wear.
years) and in persons with deformity. Ulnar implants with a precoat surface treatment introduce third-body wear into the articulation, thereby accelerating the process of bushing.

In the experience of the senior author (B.F.M.), long-term outcomes with the linked implant in persons with rheumatoid arthritis demonstrate reliable stem fixation and gratifying survival up to 25 years. Infection is more prevalent than loosening or wear.

Several traumatic conditions may be reliably managed with TEA. Acute fracture is increasingly recognized as a valid indication for prosthesis replacement in the patient aged >65 years who presents with badly comminuted fracture in osteoporotic bone. Satisfactory outcomes following TEA for acute fracture have been reported up to 7 years postoperatively (Table 1). Management of established arthrosis following previous treatment attempts is associated with almost 90% satisfactory 5-year outcomes. However, these results deteriorate over time. Persons with distal humeral non-union may present with instability as well as arthritis. Excellent results have been reported at 5 years; however, these results also deteriorate over time. Subjective patient satisfaction of >80% at nearly 10-year follow-up has been reported.

The Bryan-Morrey approach (ie, Mayo approach) for elbow arthroplasty. In this triceps-reflecting technique, Sharpey fibers are released from their insertion on the proximal ulna (arrow). The anconeus expansion and the triceps are maintained in continuity, and the entire mechanism is reflected laterally. (Reproduced with permission from the Mayo Foundation for Medical Education and Research, Rochester, MN.)

Triceps reconstruction in elbow arthroplasty. A, A cruciate drill hole technique is used to create bone tunnels anterior to the subcutaneous border. A transverse tunnel is made, as well. B, No. 5 nonabsorbable suture is placed through each tunnel and the triceps mechanism, and each stitch is locked. Stitching through the transverse hole and the tendon pulls the triceps down onto the olecranon. (Reproduced with permission from the Mayo Foundation for Medical Education and Research, Rochester, MN.)

A, To avoid direct pressure and resulting posterior ulceration following elbow arthroplasty, the arm is immobilized in full extension with an anterior splint. B, In this patient the necrosis healed spontaneously without the need for surgery.
Complications

Infection is the most bothersome complication following TEA.9 The high incidence of postoperative infection is due in part to the fact that approximately one half of candidates for TEA have rheumatoid arthritis and either have been on or are undergoing systemic treatment with disease-remitting agents. Persons with posttraumatic arthritis often have failed at least one previous operation, and these patients are also at increased risk of infection. In addition to these factors, the soft tissue around the elbow poorly tolerates multiple incisions.

Triceps insufficiency is the second most common complication following TEA.9 In general, triceps insufficiency is well tolerated. However, in some persons, it is of sufficient concern to justify a secondary reconstructive procedure. Triceps insufficiency has not been studied to any extent and, until recently, has not been addressed at all following management for sepsis.

Loosening is uncommon with current-generation linked implants. The humeral stem has a loosening rate of <10% at 2.5-year follow-up.5 Several changes have been made to the ulnar surface of the implant with the intent of improving its strength.

Table 1

| Study            | No. of Elbows | Mean Age (yr) | Fracture Type (no.)a | Mean Follow-up (yr) | MEPS (mean) | ROM (degrees) | Complications | Revisions |
|------------------|---------------|---------------|----------------------|--------------------|-------------|---------------|---------------|-----------|
| Cobb and Morrey11| 21 (20 pts)   | 72            | B1 (2), B2 (5), C2 (5), C3 (6), comminuted supracondylar (1), comminuted intra-articular fracture of the proximal aspect of the ulna (2) | 3.3 (range, 3 mo–10 y) | 95          | 105           | 5 pts (25%)  | 1 (5%)    |
| Ray et al12      | 7             | 81.7          | C2 (1), C3 (3)       | 2.7                | 92          | 110           | 1 (14%)      | 0         |
| Gambirasio et al13| 10           | 84.6          | B (2), C (8)        | 1.5                | 94          | 102           | 0             | 0         |
| Garcia et al14   | 16            | 73            | A3 (2), B3 (2), C3 (11) | 3                  | 93          | 101           | 2 (13%)      | 0         |
| Kamineni and Morrey4 | 49b         | 69            | A (6), B (5), C (38) | 7                  | 93          | 107           | 14 (29%)     | 10 (23%)c |
| Lee et al15      | 7             | 73            | A (4), B (1), C (2) | 2.1                | 94          | 89            | 1 (14%)      | 0         |

a According to the AO classification
b 43 fractures were followed for >2 years. All 49 were assessed for complications.
c One patient had two reoperations because of implant loosening.

MEPS = Mayo Elbow Performance Score, ROM = range of motion
In the experience of the senior author (B.F.M), the current-generation component, which has been in use for 9 years, has demonstrated neither mechanical loosening nor fracture following >200 implantations.

Ulnar nerve paresthesia is a common problem. However, ulnar neuropathy with motor weakness is unusual. Ulnar nerve paresthesia is typically considered to be bothersome but not functionally limiting. However, some patients experience considerable ulnar nerve irritation, which can affect the patient’s perceived outcome.

Our experience indicates that problems with wound healing have occurred in approximately 5.5% of >1,500 procedures. Several steps can be taken to reduce or eliminate wound healing problems, such as preoperative assessment with a plastic surgeon, maintaining the elbow in extension for as long as is necessary, using an anterior splint, and avoiding early motion.

### Summary

TEA is an effective and reliable procedure for managing a host of pathologic conditions. However, it is associated with a high complication rate, with infection being the most common. Attention to detail during the surgical technique can help reduce the incidence and severity of complications.

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Citation numbers printed in **bold type** indicate references published within the past 5 years.

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