Complex Bone Healing Problems

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Management of open lower extremity fractures has evolved tremendously over the past 15 years. We have what often seems like a generous number of options to treat these patients. Despite these many options, the nonunion and malunion rate of open tibial fractures continues to be as high as 16%. Due to individual compounding factors such as mechanism of injury, co-morbidities, and a patient's psychosocial situation, no patient fits into a "standard" treatment protocol. Each patient must be assessed by a team of experts in the various key treatment principles to be optimally treated for their injury.

Finally, rigid stabilization is essential in maximizing healing. External fixation has been quite successful in stabilizing complex fractures, facilitating osteogenesis and allowing for deformity correction. The fracture may require bone grafting and options include allograft bone, autologous graft, or vascularized autologous bone flaps.

As evidenced in the preceding paragraph, the key treatment principles require physicians with expertise in very different medical subspecialties. At the Denver Clinic for Bone Healing we are able to bring together orthopedic and plastic surgeons, as well as infectious disease and hyperbaric medicine specialists to develop a treatment plan with the patient and family. We have the added benefit of involving a rehabilitation specialist skilled in management of amputees if that becomes a necessary option for treatment.

It is our goal that the patient to return work in 12 – 18 months following the referral to our specialists. Key treatment principles identified for successful management include adequate surgical debridement – often a patient must return to surgery a number of times to adequately remove necrotic tissue or foreign material. It is also imperative the patient is placed on IV antibiotics with the dose and duration appropriate for the individual's situation.

Early soft tissue coverage has been identified as a factor that improves the overall outcome. Choice of coverage varies with the soft tissue deficit, (i.e. skin graft, wound vac, or vascularized muscle flap) and patient lifestyle. Coverage may be done prior to final bone fixation, requiring the soft tissue graft be elevated during the fixation procedure.

Recommended articles
Case Study #1

PHYSICIANS
Drs. David B. Hahn (orthopedic surgeon) and David Schnur (microvascular surgeon)

DIAGNOSIS
Tibial nonunion with bone loss, external rotation and Achilles contracture

HISTORY
This healthy 23-year-old Spanish-speaking male was working as a framer on a construction site in Colorado Springs on 6/19/06 when a beam fell 8’ onto his right lower extremity causing a crush injury. He underwent debridement and placement of an external fixator for a grade 3 open fracture of the proximal third of his tibia. He was subsequently transferred to another hospital across his legs. This occurred 1/10/07. He was taken to a local hospital where he emergently nailing on 6/26/06 and eventual iliac crest bone grafting on 8/21/06. In addition, he had sustained a 1st metatarsal fracture which was repaired.

CLINICAL EXAM
He presented to Extremities at Risk in late September ’06 with a translator and his case manager. On exam, his knee was stable with flexion to 130°, and no effusion. He had well-healed incisions over the knee and fracture site, and soft tissues were otherwise intact without evidence of infection. He had a 20-25° external rotation deformity of the distal tibia with a 15-20° equinus contracture. He was able to dorsiflex and plantarflex and had intact sensation in his foot. Radiographs revealed a proximal third tibial fracture with significant comminution and a 5cm bone defect; his fibula was intact (Fig 1). A locked nail spanned the fracture site and appeared in good position. Also apparent was a healed metatarsal fracture. The patient did express some concern about his foot turning outward and walking on his toes.

Since the patient was a non-smoker, with no evidence of infection and only 3 months out from injury, it was agreed to begin with rotational osteoclasis of the tibial fragment to straighten the leg. At the same time he underwent a percutaneous tendo-Achilles lengthening to straighten his foot. Once the fracture had time to declare itself and the amount of bone loss was determined, surgical options to be considered included bone transport with a spatial frame, vascularized bone transfer of his scapula or fibula, or a frozen structural allograft.

TREATMENT
He underwent correction of the equinus and external rotation deformities in October and embarked on a course of physical therapy to strengthen and increase range of motion in his knee, ankle and great toe. His progress, however, was slow and a worsening flexion contracture of his great toe interfered with rehabilitation. In February he underwent IP joint fusion of his great toe, dynamization of the rod and percutaneous grafting to stimulate fracture healing. A CT scan in April — nearly 10 months out from injury — revealed a persistent bone defect of approximately 5cm, with very little if any bridging of the anteromedial aspect of the tibia (Fig 2). His case was presented for discussion at the Extremities at Risk weekly conference. It was recommended that the best option was to obtain an arteriogram to confirm adequate vascular supply and then proceed with transfer of vascularized bone to the nonunion site. His arteriogram was normal, showing patency of all three vessels. On 6/29/07 he underwent transfer of an osteocutaneous portion of his left scapula and latissimus (Fig 3) to the right proximal tibia (Fig 4). Vein grafts to the arterial and venous pedicles of the scapular flap were fashioned and a split thickness skin graft was performed.

RESULTS
Postoperative films at 6 months revealed the intramedullary rod was in place, his fibula was solidly healed, and the scapular graft demonstrated 80-90% continuity with the host tibia (Fig 5). The alignment in his foot was very good and his great toe functioned well. Overall the lower extremity was reasonably aligned and he walked very well despite a slight antalgic gait due to muscle weakness. At this point he will need vigorous physical therapy of his entire lower extremity, including strengthening of his hip extensors and abductors. It is expected that after a few months his gait will improve and he’ll be back to near normal activities.

Case Study #2

PHYSICIANS
Drs. David Hahn, Cynthia Kelly (orthopedic surgeons), David Schnur (microvascular surgeon), Matthew Terra (infectious disease), and Robert Meier (physiatrist)

DIAGNOSIS
Right traumatic BKA and left lower extremity near-amputation from gas explosion

HISTORY
The patient is a 23-year-old who was transferred from the Western Slope following severe injuries to both lower extremities. He had been working in a gas field on a drilling rig when there was an explosion and a large piece of metal hit him across his legs. This occurred 1/10/07. He was taken to a local hospital where he emergently underwent open trans-tibial amputation on the right side. The left tibia with a grade III open mid-shaft fracture was debrided and an external fixator placed. Given the severity of his injuries, he was transferred to Extremities at Risk for further evaluation on 1/12/07.

CLINICAL EXAM
A dressing was in place on the right below knee amputation. The left lower extremity was stabilized with an external fixator. His left foot was sensitive with palpable pulses and a flicker of dorsiflexion and plantar flexion as well as extension and flexion of the toes. He was otherwise very healthy, medically stable, with no significant medical history (Fig 6).

TREATMENT
Dr. Schnur took the patient to surgery the morning after transfer and re-debrided the right
Case Study #2 Continued

residual limb and left tibia, covering both limbs with antibiotic bead pouches. A few days later, Dr. Cynthia Kelly re-debrided the residual limb and performed a secondary closure of the BKA. After multiple washouts and fixator adjustments, his case was presented at the weekly Extremities at Risk conference for discussion of reconstruction options of the grade 3 open fracture with 10 cm of bone loss. The consensus was to work on rehabilitation of the BKA, and to perform an intercalary tibial allograft of the left where there was 10 cm of missing bone. He was taken to surgery for fixator removal and placement of an antibiotic-impregnated cement spacer (Fig. 7). The spacer was fixed with two locking plates and the soft tissue defect covered with a latissimus dorsi flap. Over the next two months the soft tissues of both extremities healed nicely and by March he was fit with a below knee prosthesis on the right. He continued to work on gait training and rehabilitation, amputating with his prosthetic leg and forearm crutches. Throughout this time he was managed by Dr. Terra for positive cultures of multiple staph species. On May 1st he underwent elevation of the flap, removal of the spacer and allograft transplantation, a type of reconstruction often used in tumor surgery (Figs 8,9). The intercalary allograft was a fresh-frozen tibial graft processed by the local tissue bank (AlloSource, Denver CO). At the time of surgery, the graft was cut to match the size of the tibial defect, filled with antibiotic cement and fixed in place with plates and screws.

RESULTS

At the patient’s last clinic visit in March 2008, he was doing remarkably well. Standing films showed reasonable alignment and solid healing of the allograft on the left side and he had no problems with the right leg amputation (Fig 10). His right BKA continues to improve with regard to function, and is his “better leg” at this point. The strength of his left leg is making steady improvement and the function of his foot is improving as well. The left lower extremity hardware will remain as structural support, with this leg ultimately becoming his “normal” leg. He has continued to receive career counseling since his main focus at this point is future employment and resuming the financial support of his young family.

Case Study #3

PHYSICIANS

Drs. Ross Wilkins, David B. Hahn (orthopedic surgeons) and Ray Blum (infectious disease specialist), Gary Snider (plastic surgeon)

DIAGNOSIS

Infected nonunion of the tibia

HISTORY

The patient was 15 years old in November of 2001 when, as a cross-country runner, he developed a stress fracture of his tibia. Shortly after being diagnosed with the stress fracture, he was involved in a motorcycle accident and sustained a closed mid-shaft fracture in the area of the stress fracture. He underwent an ORIF with an intramedullary rod. After 1 week he developed significant erythema and blistering over the area of the incision. This went on to become a chronic draining wound.

He had an episode of severe pain a few weeks after his surgery. X-rays revealed the original fracture had healed but there was a second fracture in the area; an MRI of the tibia was consistent with osteomyelitis in the area.

TREATMENT

He presented to the physicians of the Denver Clinic for Extremities at Risk in June of 2002, and had consultations by RMW, RB, and DBH, and GS. Due to the osteomyelitis in the area the IM rod was removed, cultures taken, and an external fixator placed to support the fracture. His course was quite involved, requiring multiple I&Ds with antibiotic bead exchanges and soft tissue free flap coverage.

In September of 2003 he was diagnosed with a persistent non-union. He underwent I&D followed by bone marrow aspirate with demineralized bone matrix (DBM) injections to the area. A-0 plate fixation was utilized at this time (Fig 11). He underwent repeated I&Ds with bone marrow aspirate (DBM) injections and demonstrated progressively increasing amount of callus formation at the non-union site.

In December of 2005 he presented with increased pain. X-ray revealed broken screws in his tibial hardware. He was then diagnosed with an infected non-union of the tibia. It was decided to proceed with radical debridement and spatial frame bone transplant treatment (Fig 12). He underwent hardware removal and radical sequestrectomy where approximately 6cm of tibia and 2 cm of fibula were excised and antibiotic beads placed. Cultures were positive for staph A so he was started on IV antibiotics. He initiated the transport process at 0.5mm/day, and was monitored weekly to assure attention was paid to neurovascular status, leg length, and that adequate bone regenerate was forming in the area. Lengthening continued until February of 2007, but due to weak appearing bone on CT a process of destabilizing the frame was initiated. Over a period of the next 5 months the frame was slowly destabilized, as he carefully increased his weight bearing. This process, which was monitored by at least twice monthly office visits, allowed for improvement in bone strength, and finally removal of the frame in July of 2007 (Fig. 13). He had healed both areas, the regenerate, where his body made new bone and the previous non-union site (the docking site).

RESULTS

This difficult course with multiple debridements, a long course of antibiotics, and constant monitoring of his soft tissue status and bone healing required careful planning of the team of physicians with Extremities at Risk. At his most recent follow-up visit in November of 2007 he was walking without any assistive device and has no limp. His leg length difference was 7 mm which is accommodated by using a lift in his shoe. He has slight procurvatum of his tibia as well as slight varus. He is able to bicycle for exercise and is interested in starting to run again.
**EVERY THURSDAY**

Extremities at Risk hosts a multidisciplinary conference on Thursday morning from 7:00 – 8:00 a.m. in the Colorado Room North (across from the library entrance) at Presbyterian/St. Luke’s Medical Center. Healthcare professionals are welcome to attend this CME-accredited program. If you have a patient that you wish to present either for discussion of a treatment plan or for input from the group, please notify Vera Murdock, Patient Referral Coordinator, at 303-839-6294 or (800)262-5462.

**EDUCATIONAL CALENDAR**

**Humeral Non-Unions: Use of the Pedicled Lateral Border of the Scapula**
Ross Wilkins, MD
Canadian Orthopaedic Association/American Orthopaedic Association
Combined Annual Meeting
Quebec City, Quebec
June 6, 2008

**Humeral Non-Unions: Use of the Pedicled Lateral Border of the Scapula**
Poster presentation

and

**How to Keep Out of Trouble: Oncology and the General Surgeon**
Podium presentation with R. Lor Randall, MD (University of Utah)
Cynthia Kelly, MD
Western Orthopaedic Association
Annual Meeting
Maui, Hawaii
July 23 – 26, 2008

**Limb Preservation Foundation News**

Make plans now to join 9News Anchor Adele Arakawa and other Foundation golfers at the 9th Annual Tom Arganese, M.D. Memorial Golf Tournament that will take place on Monday, July 28 at the beautiful Inverness Hotel & Conference Center in Englewood, CO. Registration is currently underway for this year’s Tourney that benefits The Limb Preservation programs, education and research effort in the campaign to Save Limbs & Lives. Entry is $250/golfer (prior to July 4 and $275/golfer after July 5) and includes: Green Fees, Golf Cart, Range Balls, Continental Breakfast, Tournament Awards Luncheon and Player Goody Bag.

For information on the 2008 Tom Arganese, M.D. Memorial Golf Tournament, visit The Limb Preservation Foundation website at www.limbpreservation.org or contact Martha Simmons (303/217-0998 or martha@limbpreservation.org).

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