supporting the use of HBOT in post-traumatic infections and the single study with a control arm reported no benefit.

REFERENCES

3.2. TREATMENT: SURGEON AND CARE TEAM

QUESTION 1: Should all infected non-unions be treated in specialized septic centers?

RECOMMENDATION: The current literature, although rich in case series and observational studies, does not lend support to the recommendation that “specialized septic surgery centers” should care for infected non-unions. However, because of the complexities of infected non-unions, care in specialized centers may yield the best possible outcome.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 70%, Disagree: 21%, Abstain: 9% (Super Majority, Weak Consensus)

RATIONALE
Infected nonunion is the persistence of an infection at the fracture site and the surrounding tissue and failure of bone healing for eight months, (U.S. Food and Drug Administration). It could be considered as an osteomyelitis at an unstable fracture before the debridement and which remains unstable thereafter. It is commonly accompanied by soft tissue problems, adjacent joint stiffness, motor and sensory dysfunction of the limb, chronic pain, depression and unrelated medical problems leading to considerable physical, social, financial and mental impact on the life of the patient and the healthcare systems and may even become a limb-threatening complication.

Bone healing and eradication of the infection is the main but not the only objective because a non-functional and deformed limb with pain and stiffness of the adjacent joints will be an unsatisfactory outcome even if at some point the bone heals sufficiently. Treatment is aimed at returning the extremity and the patient to the fullest function possible during and after the treatment process. This process is usually long-lasting and must be planned accordingly so that in case of failure, further treatment alternatives remain available. Because of the various nonunion types and the multitude of possible problems related to the patient’s health and comorbidity, such as prior treatments and the bone and soft tissue defects, no simple treatment algorithms are possible. The recommended strategy, with an array of management alternatives, is: (a) the “infection-elimination first” by local radical debridement of all pathological tissue, followed by (b) tissue and bone reconstruction and (c) targeted chemotherapy with local and systemic antibiotics. A specialized team of orthopaedic surgeons with expertise in a broad spectrum of techniques must thoroughly evaluate the patient and carefully consider all available information about the general health status and the local tissue conditions. The prior failed treatments must be taken into account, as well as the optimization of all treatment modifiers. Where extensive surgical exposures have failed consideration is given to less invasive techniques that respect the surrounding soft tissues. Stable fixation, adequate vascularity, bone-to-bone contact, and bone grafting or strong bone regenerate are crucial factors for success. The potential need for future treatment should be considered when pursuing any particular intervention.

The care of the patients with infected nonunions may be best performed at specialized septic surgery centers with an expert team approach to achieve the ultimate goals of bony union and restoration of alignment and function, while limiting the extent of residual disability. A medical center that treats infected non-unions should provide all of the appropriate resources and a supportive team of consulting specialists to contribute to all aspects of care, both at the initial evaluation and throughout the course of treatment. The role of anesthesiologists is obvious as well as of the internists for patients with serious medical conditions. Plastic surgeons are often necessary to reconstruct the soft tissues...
after serial debridement and vascular surgeons may be required if the vascularity of the limb is in question. A multidisciplinary treatment team should be utilized in providing comprehensive care, including a pain management specialist, a psychiatrist to support patients with clinical depression, a neurologist to evaluate motor or sensory loss, a dietician to optimize the nutritional status, and physical and occupational therapists to facilitate rehabilitation. Microbiology and histopathology labs with the availability of modern diagnostic facilities, an experienced clinical pharmacologist and an infectious disease specialist are all integral parts of the multidisciplinary unit as well.

**APPENDIX - SEARCH STRATEGY**

There is no study in the literature that has evaluated this particular issue. We have conducted a broad literature search trying to identify articles or parameters that could lead us to musculoskeletal infection specialist centers, although the number of true, dedicated centers with multi-disciplinary units at this time remains very low. Medline, Cochrane, and Embase databases were searched, employing the terms: “infected nonunions,” “septic nonunions,” “specialist’s septic centers,” “infected nonunion AND hospital” and “infected nonunion AND septic center.” After removing papers that did not match our criteria we ended up with 69 articles, which were all observational case series for infected nonunions. Out of those we identified 28 articles (all level IV) that could be used for our analysis. Hospitals with level I trauma centers that had a minimum of two publications about infected nonunions were classified as “specialist centers” (group A) [1-15]. Orthopaedic departments with only one publication were categorized as “non specialized septic centers” (group B) [16-28].

In total, there were 15 publications from 10 centers in group A, and 13 publications from an equal number of centers in group B. Regarding the different treatment methods, in group A, 60% were treated using external fixator to stabilize the infected nonunion, 20% used open reduction and internal fixation (ORIF), 5% intramedullary (IM) nailing and the remaining used more than one technique. In 67% of the patients in group A a bone graft was used, whereas in group B only 38% mention using bone grafting. For the fixation of the bone in group B, in 54% external fixation were applied, 15% used IM nails, 7.7% ORIF, while the rest report the use of more than one technique (external fixators and plates). Most studies do not report the length of hospital stay and time for return to work. In addition, not all of them give data about limb shortening and alignment. The average number of patients in the studies was relatively small. Given also the heterogeneity of anatomical locations of the nonunions among the different studies, valid comparisons are not possible. The number of previous operations was comparable: 2.9 in group A, and 3.1 in group B.

In 54% of group A centers, the infected nonunions were treated in one stage and 46% in two stages. In group B, 73% of the patients were treated in one stage and 27% in two stages. Thirteen studies analyzed the outcomes of treatment with the Ilizarov method, nine studies analyzed the management with a single-stage or two-stage approach and use of cancellous bone grafting, three studies involved vascularized bone grafting, and one study involved a bulk allograft. Follow-up was higher in group A (46.4 months) compared to group B (37.3 months). Both groups demonstrated similar outcomes with respect to the elimination of infection. However, parameters such as length of hospital stay, time to bone healing, time until return to work, functional outcomes and patient reported outcome measures are not available, thus markedly limiting the strength of the recommendation.