

## **Staged treatment is superior to single stage treatment for infected humeral nonunions**

Patrick Pallitto, Nathaniel T. Koutlas, Noah James Harrison, William T. Obremsky<sup>1</sup>, Alexander Hysong, Samuel Posey, Joseph R Hsu, Andrew Chen<sup>2</sup>, John David Adams, Benjamin Averkamp<sup>3</sup>, Komi Eddie Afetse, Randi Alexander, Rodney Yeboah Arthur, Benjamin Averkamp<sup>3</sup>, Sharon N Babcock, Gisele Bailey, Amy A Bauer, Kayla Rose Bell, Ainsley Katherine Bloomer, Lucy Charlotte Bowers, Matthew Braswell<sup>4</sup>, Landon Bulloch, David Stoddy Carey, Christine Churchill<sup>5</sup>, Samuel Cohen-Tanugi<sup>6</sup>, Mario Cuadra, Malcolm DeBaun, Jarrod Edward Dumpe, Hassan Farooq<sup>7</sup>, Michael J Gardner<sup>8</sup>, Steven Thomas Greene<sup>9</sup>, Stephen A Hemmerly, Anna Hemminger, Martha B Holden, Zachery Lynn Hong, Christopher Joseph Jamero, Tracy Jones Johns<sup>10</sup>, Josef Jolissaint<sup>11</sup>, Jenna K Jones, Madhav A Karunakar, Laurence Kempton<sup>12</sup>, Kamryn McKenzie King, Shreyas Kudrimoti, Cara Lai, Scott M Lewis, Luke A Lopas, David Macknet<sup>13</sup>, Clayton Maschhoff, Julia Mastracci, Paul Edward Matuszewski<sup>14</sup>, Laura McLean, Joseph Michalski, Anna Noel Miller<sup>15</sup>, Hassan Riaz Mir<sup>16</sup>, Roman Natoli, Susan Marie Odum<sup>12</sup>, Alexander G Padovano, Tyler J Pease, Daniel Pereira, Katheryn Marianne Peterson, Kayla Pfaff, Kevin Daniel Phelps<sup>12</sup>, Sarah Pierre<sup>17</sup>, Hannah R Pollock, Olivia Rice<sup>3</sup>, Jessica C Rivera, Elsa Beatriz Rodriguez, Tamar Roomian, Marc Schatz, Ryan Seltzer, Rachel Seymour<sup>5</sup>, Ishani Sharma, Jigyasa Sharma, Stephen H Sims<sup>18</sup>, Rebecca G Snider<sup>19</sup>, Gabriel James Sowards, Lisa Stang, Thomas Scott Stang, Amber Nicole Stanley, Gabriella Stribling, Stephanie Lewis Tanner<sup>20</sup>, Lauren Maccormick Tatman<sup>21</sup>, Bailee Taylor, Noelle Lily Van Rysselberghe<sup>22</sup>, Harsh Wadhwa<sup>22</sup>, Meghan Wally<sup>12</sup>, Andrew Donald Wohler, Ziqing Yu, Robert D Zura<sup>23</sup>

<sup>1</sup>Vanderbilt Ortho Inst, <sup>2</sup>UNC Orthopaedics, <sup>3</sup>Carolinas Medical Center, <sup>4</sup>Atrium Health Mercy, <sup>5</sup>Atrium Health, <sup>6</sup>Carolinas Medical Center - Atrium Health, <sup>7</sup>Loyola University Health System, <sup>8</sup>Stanford University Sugery, <sup>9</sup>University of Mississippi Medical Center, <sup>10</sup>Atrium Health Navicent Medical Center, <sup>11</sup>Orthocarlina/Cmc, <sup>12</sup>Atrium Health Musculoskeletal Institute, <sup>13</sup>Atrium Health System, <sup>14</sup>University of Kentucky, <sup>15</sup>Washington University In St. Louis, <sup>16</sup>University of South Florida, <sup>17</sup>San Antonio Military Medical Center, <sup>18</sup>Carolinas Med Ctr, <sup>19</sup>Prisma Health, <sup>20</sup>Prisma Health - Upstate, <sup>21</sup>University of Minnesota, <sup>22</sup>Stanford University, <sup>23</sup>LSU Health New Orleans

**INTRODUCTION:** Humeral nonunions are challenging to treat. Even after successful revision surgery, full functional recovery is limited. The surgical treatment of aseptic humeral nonunions is well documented, but the literature is limited regarding the treatment of infected humeral nonunions. Although thorough debridement, irrigation, and systemic antibiotics remain the cornerstone in the treatment of an infected nonunion, it is unclear what the overall union rate is after surgical treatment.

**METHODS:** We performed a retrospective analysis of a database of 2,012 long bone nonunions. Within the database are 271 humeral nonunions gathered from 9 level I trauma centers. We searched these humeral nonunions to identify those that were infected prior to the nonunion procedure. A nonunion was considered septic in the presence of a draining sinus or positive intraoperative cultures. Standard patient demographics, fracture characteristics, fixation techniques, bone grafting, intraoperative culture results, and complications were collected. The primary outcome was overall union rate. Secondary outcomes included post-operative complications.

**RESULTS:** A total of 33 patients with an infected humeral nonunion after initial surgical fixation that met inclusion criteria were identified with adequate follow-up. The mean follow-up time for a confirmed infected nonunion was 17.3 months. The median age at the time of index injury was 50, and although it trended towards younger (36) in those that ultimately united, this was not statistically significant ( $p < 0.13$ ). Of the initial injuries, 43.5% were open. The initial fixation construct in the majority of patients were plate and screws (81%). 94.1% of patients with a positive culture grew a single organism. The definitive nonunion procedure for infected humerus nonunion was successful only 51% ( $n=17$ ) of the time. Pre-planned staged treatment was associated with successful union (76.5% vs 37.5%,  $p < 0.024$ ). Postoperative complications were seen in 53.1% of patients and significantly more common in the persistent nonunion group (68.8% vs 25.0%,  $p < 0.013$ ). Tobacco use, diabetes, BMI, and bone grafting did not appear to impact union.

**DISCUSSION AND CONCLUSION:** This study supports our hypothesis that infected humeral nonunions are challenging to treat and are at high risk for persistent nonunion (48.5%). These findings suggest that further research into the best treatment strategies for infected humeral nonunions is needed, and staged treatment is a promising strategy.