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HIP ARTHROPLASTY

Conversion total hip arthroplasty following extracapsular hip fracture fixation with a cephalomedullary device: a comprehensive review

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Abstract

With the annual incidence of hip fractures and hip fracture fixation rising, the need for conversion total hip arthroplasty has also risen. About half of the 280,000 hip fractures that occur annually in the United States are extracapsular. Commonly extracapsular hip fractures are treated with either cephalomedullary nails (CMNs) or sliding hip screws (SHS). More recently, there has been a shift toward increased CMN use due to increased training with this fixation method as well as perioperative and biomechanical benefits. Given this shift, orthopedic surgeons need to understand the factors that lead to CMN failure. Failed CMN treatment leaves both patients and surgeons with few management options including revision fixation with or without osteotomy, conversion total hip arthroplasty, and conversion hemiarthroplasty. Surgeons must consider the patient and injury characteristics before deciding the best treatment plan. Conversion total hip arthroplasty is indicated in younger patients without femoral head and/or acetabular articular injury, degenerative joint disease, or avascular necrosis. Conversion total arthroplasty is a technically demanding and resource-intensive surgery associated with lower success rates and outcomes than primary total hip arthroplasty. Orthopedic surgeons should have thorough understanding of preoperative workup needed prior to surgery, implant selection associated with best outcomes, most common surgical approaches used, intraoperative considerations, and complications associated with conversion total hip arthroplasty. A comprehensive understanding of these concepts gives patients the best chance of having a successful outcome.

Keywords Conversion total hip arthroplasty · Extracapsular hip fracture · Cephalomedullary device

Introduction

In the United States, over 280,000 hip fractures are reported annually with a predicted increase to as high as 840,000 hip fractures per year by 2030 [1–3]. Almost half of these fractures are extracapsular [1]. Operative treatment of these injuries improves patient outcomes by enhancing patient mobility and independence.

Typically, extracapsular hip fractures are treated with a cephalomedullary nail (CMN) or sliding hip screw (SHS). Multiple studies in America and abroad demonstrate that early career surgeons prefer cephalomedullary devices over extramedullary sliding hip screw constructs [1, 4, 5]. This shift to cephalomedullary fixation is due to surgeon training, decreased operating room time, decreased blood loss and superior biomechanical stability [4]. Fixation failure occurs in 1.2% to 9.6% of these patients [5, 6], often requiring conversion total hip arthroplasty (THA) [5–7].

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Conversion THA is associated with higher complication rates and is often complicated by altered anatomy, presence of adhesions, need for hardware removal, poor bone quality, and potential need for revision-type arthroplasty implants [5, 6, 8]. As the need for conversion THA increases, surgeons must be aware that these procedures more closely resemble revision THA and that potential pitfalls are associated with these complex procedures.

Failure of cephalomedullary fixation and conversion THA indications

Cephalomedullary nails are increasingly utilized for all variations of extracapsular proximal femur fractures, including intertrochanteric, pertrochanteric, and basicervical proximal femur fractures [4, 9, 10]. There is little evidence that demonstrates differences between CMNs and SHS with respect to functional outcomes, complications, loss of reduction, union rate and mortality [4, 10]. Failure of these constructs has been extensively studied. Basicervical fractures may have greater inherent biomechanical instability when compared to other extracapsular proximal femoral fracture patterns [4, 9, 11]. Watson et al. noted 6 of 11 patients with a basicervical femoral neck fracture treated with CMN had failure of fixation [4]. Similarly, Lee et al. demonstrated in their series of 69 basicervical femoral neck fractures that 26% had collapsed after treatment with either a SHS or CMN and that 8.6% were converted to THA after fixation failure [9]. Su et al. compared intertrochanteric fractures to basicervical femoral neck fractures and found that basicervical fractures had significantly more collapse [11]. There is considerable debate regarding which device is best for fixation of basicervical femoral neck fractures. However, the CMN has the following theoretical advantage: the CMN is closer to the mechanical axis of the body center, decreasing the bending moment of the implant, and as collapse of the fracture site occurs, the CMN can buttress the medial cortex of the proximal fragment and prevent further collapse [9].

Preoperative understanding of the injury pattern and stability, intraoperative reduction, and implant positioning are critical when utilizing CMNs [12]. Malreduced fractures and unstable fractures that displace into varus are at high risk of fixation failure, necessitating conversion THA. Hoffmann et al. reported that fixation failure in intertrochanteric fractures with a CMN was unrelated to implant choice, implant material, or fracture pattern, but was instead influenced by reduction quality. In patients with a neck shaft angle < 125, the rate of fixation failure was 11.1% compared to 2.6% in patients with a neck shaft angle ≥ 125 [10]. In 1995, Baumgaertner et al. defined the tip–apex distance as the most significant predictor for cutout of the lag screw in the SHS construct with < 25 mm associated with a lower rate of cutout [13]. Further studies have corroborated that the tip–apex distance is also the best predictor of screw cutout with the use of the CMN [4, 13, 14]. Overall, CMN utilization for extracapsular hip fractures is a reliable technique. However, several factors as discussed can affect the likelihood of success.

Conversion THA is a salvage procedure indicated for patients with failed CMN treatment, which is typically the result of screw cutout, nonunion, post-traumatic arthritis, or avascular necrosis (AVN) of the femoral head. Historically, failure of internal fixation of intertrochanteric fractures has been reported to be between 3 and 12%, with device penetration accounting for 2 to 12%, nonunion for 2 to 5% and varus malunion between 5 and 11% of patients [8]. Zhang et al. evaluated the mechanism of failure of 19 patients who underwent conversion THA following failed internal fixation of an intertrochanteric fracture with a SHS. He observed nonunion with lag screw penetration in eight patients, AVN of the femoral head in ten patients and infection in one patient [8]. Zeng et al. also reviewed 72 patients with prior CMN placement for intertrochanteric fractures that subsequently underwent conversion THA. In this cohort, 24 patients had screw cutout, 21 nonunion, 16 AVN, and 11 patients with insufficient initial fixation (Figs. 1 and 2) [6, 8, 15].

Treatment considerations

The surgeon must consider the patient and injury characteristics when deciding on the optimal treatment plan, which may include conversion THA, conversion hemiarthroplasty, revision fracture fixation and osteotomy. The choice of treatment is based on multiple factors, including patient age and activity level, bone quality, and the presence of proximal femoral bone loss and articular cartilage injury.

Surgeons may prefer revision internal fixation or osteotomy in physiologically younger patients who have a long-life expectancy. The treatment decision needs to consider the condition of the femoral head. In younger patients with an intact femoral head and good bone stock, revision internal fixation can be considered, however, if significant varus deformity exists then the surgeon should consider valgus osteotomy and internal fixation [16]. Conversion THA is indicated in younger active patients with femoral head and/or acetabular articular injury, degenerative joint disease, or AVN. Hemiarthroplasty is indicated when there is no articular cartilage injury in low-demand patients [17].

Preoperative planning

Conversion THA is often a technically demanding and resource-intensive procedure performed in patients with poor functional capacity. Lower success rates and outcomes

Fig. 1 Radiograph demonstrating screw cutout in a patient treated with a cephalomedullary nail for an extracapsular hip fracture

Fig. 2 Coronal computed tomography scan demonstrating a nonunion of an extracapsular hip fracture treated with a cephalomedullary nail

are expected than in primary THA [8, 18]. Thorough preoperative evaluation including radiographs (AP pelvis, AP and cross-table lateral hip), CT hip if indicated, laboratory evaluation [CBC with differential, basic metabolic panel, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR)] and thorough physical examination (scar evaluation, clinical leg length evaluation, foot drop evaluation, neurological and gait assessment) are needed.

In addition to obtaining standard preoperative labs and medical clearances prior to the procedure, occult infection should be considered as a potential cause of failed internal fixation. If there is any concern for potential intraarticular infection, a hip arthrocentesis should be performed preoperatively to evaluate synovial fluid. In the case of extra-articular proximal femur fractures, if inflammatory labs are elevated, frozen sections should be obtained intraoperatively. If there are signs of infection, consideration should be given to performing a 2 staged revision with initial removal of all hardware, irrigation, debridement and an organism-specific antibiotic plan to eradicate the infection prior to conversion THA [19]. In the absence of infection, surgeons may consider a staged procedure for patients with significant comorbidities that are in critical condition after removal of the internal fixation device. The rationale for this should be discussed with the patient preoperatively and the decision can be made intraoperatively [20, 21].

Careful preoperative templating utilizing the appropriate images should be done to ensure that the correct implants and instrumentation are available prior to the case. To facilitate CMN removal and conversion THA, the surgeon should ensure the following instruments are available at the time of the procedure: manufacturer-specific explant tools if needed, a universal cone-shaped femoral cephalomedullary extraction device (Fig. 3), femoral canal reamers (opening reamer may be used to remove heterotopic bone from the cephalomedullary device), implants for fracture prophylaxis or treatment (cerclage wires or cables, hook plates) and extensively coated monobloc femoral component or modular fluted titanium stems.

The required removal of an internal fixation device can be difficult due to scar tissue requiring extensive dissection and increased operating time and higher blood loss [22]. In CMN, patient's heterotopic ossification at the site of nail insertion can make dissection and exposure challenging and increase blood loss. Malunited or nonunited proximal femur fragments are usually in an altered position and may require mobilization or

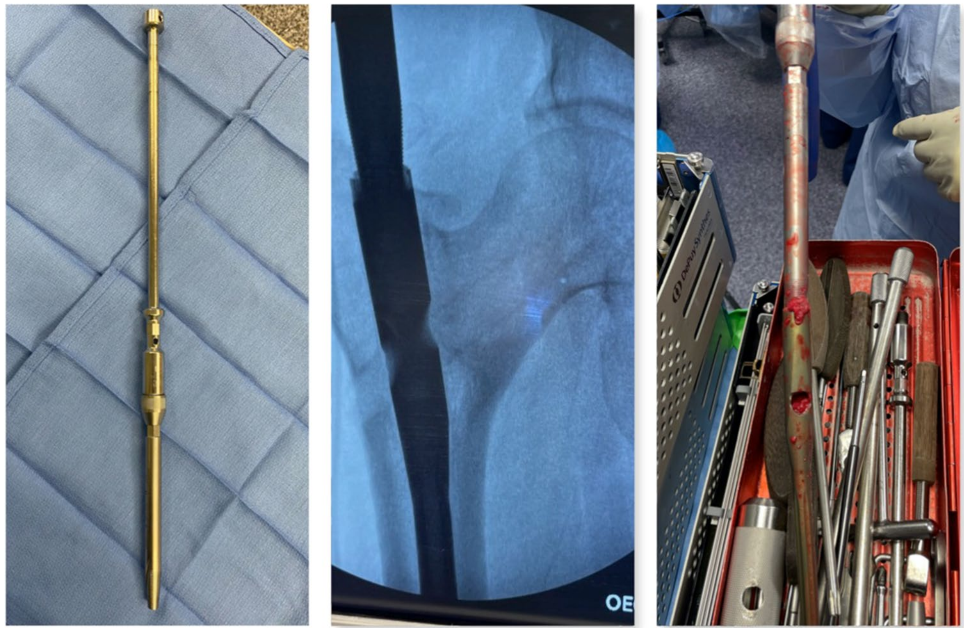

Fig. 3 **A** Photograph demonstrating the tapered cephalomedullary nail extraction device. **B** Intraoperative radiograph demonstrating the use of a tapered extraction device. The extraction device is threaded into the proximal portion of the cephalomedullary nail and a slotted mallet is used to remove the nail. **C** Intraoperative photograph after removal of the nail, with the extraction device threaded into the nail proximally

excision [23]. Bone loss below the typical neck-resection level for hip arthroplasty is common, and build up with a calcar-replacement or distally fixed femoral implants are required to bypass bone defects.

It can often be difficult once the hardware is removed to determine the level of the femoral reconstruction. However, a reasonable reference is to restore the relationship of the tip of the greater trochanter to the center of the femoral head. Intraoperatively this can be difficult and surgeons should consider using intraoperative trialing with radiography in an attempt to restore limb length, proximal femoral offset, and to evaluate implant positioning [24].

Wagner-style femoral stems, with or without modularity, facilitate durable implant fixation, restore soft tissue tension and leg length [19, 25]. Poor bone quality from pre-existing osteoporosis and subsequent disuse osteopenia after failed internal fixation is common [8]. Bone defects, altered bony landmarks, poor bone quality, and presence of screw holes enhance the risk of intraoperative fractures, and can make the placement of the revision femoral component difficult [26]. Plan for cerclage wire or cables and supplemental prophylactic fixation routinely. The surgeon must be facile with implant removal techniques, extensile approaches, and techniques required for stable fracture fixation. High-speed drills, metal cutting burrs, and broken screw removal equipment are often very helpful.

Implant selection

When hip arthroplasty is used to treat failed internal fixation of extracapsular proximal femur fractures, the standard goal is for stable femoral fixation. The inferomedial calcar bone deficiency in these patients may lead to an atypical level of resection compared to primary THA; therefore, having a ‘calcar replacing’ or a modular stem may be necessary. Longer, diaphyseal fit implants are required when distal bypass of stress risers is deemed necessary. The extent of distal bypass required is controversial, as defects under 20 to 30% of the bone diameter showed no significant reduction in torsional strength in one study [8]. Generally, a distance of two cortical diameters is preferred, but this depends on the location and extent of implant engagement, host bone quality, and the significance of the stress riser [21].

Both cemented and uncemented conversion THA designs have been successfully used for the treatment of failed fracture fixation [15]. Several studies report the use of cemented arthroplasty with good to excellent results [8, 19, 26]. However, difficulty arises in the containment of the cement when it is pressurized into the femoral canal, as extravasation of cement through screw holes and fracture lines may lead to suboptimal pressurization of cement [26].

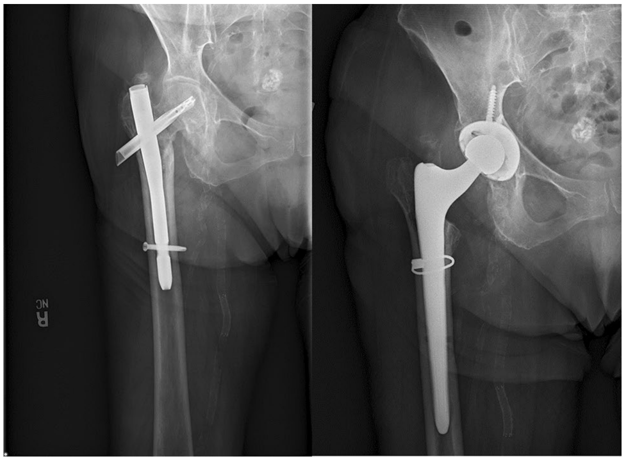

Fig. 4 **A** Preoperative radiograph demonstrating nonunion of an extracapsular hip fracture treated with a cephalomedullary nail. **B** Postoperative radiograph following conversion THA with a fluted titanium femoral stem

While defects can be occluded prior to or during cementation with a gloved thumb, bone plug, firmly packed gauze or other manner to allow for appropriate pressurization, the risk of suboptimal cement pressurization remains [8]. Because of the limits to successful cementation, cementless prostheses, either with extensively coated monobloc stems or with fluted modular tapered titanium stems may be preferred (Fig. 4).

Modular femoral stems can be useful when significant proximal femoral defects are present and distal engagement is required. This is seen in the proximal femur after removal of a CMN due to the wider diameter of the device proximally (typically 14–18 mm) [27]. Solid initial distal fixation is a critical requirement for successful reconstruction in these cases and a modular stem separates this step of the procedure from other aspects of the conversion procedure including offset restoration (important for abductor strength and function), leg length equality, and hip stability [28]. It is important to note, however, that the fracture of modular cementless femoral stems at the mid-stem junction is an intractable problem, especially in these patients with inadequate proximal osseous support because of nonunion of the proximal femur fragment [26]. Prevention of this catastrophic outcome may be achieved by choosing a suitable femoral stem with a large diameter or XL junction and reinforcing the proximal bone stock with a medial strut graft that can aid in long-term buttressing and support of the proximal portion of the implant [29].

Both THA and hemiarthroplasty are reliable treatment methods for failed extracapsular proximal femoral fracture fixation. However, Cho et al. reported better functional outcomes in patients undergoing salvage THA compared to hemiarthroplasty for failed intertrochanteric femur fixation [30]. Decisions regarding acetabular resurfacing relate to the quality of the remaining cartilage, presence of AVN, the pre-fracture activity of the patient and the surgeon's preferences [19, 31].

Surgical approach

In deciding which approach to utilize, the surgeon must consider the extent of the surgical approach (as multiple incisions may be necessary) as well as whether or not an extensile approach may be needed for the removal of the CMN [32]. Historically, most surgeons have preferred to utilize either the posterior or anterolateral (Watson Jones) approach [5, 8, 27], but a recent study has highlighted the possible utility of the direct anterior approach (DAA) for conversion THA [21]. Surgeons should be aware of the difficulty that conversion THA presents and use an extensile approach that the surgeon is comfortable and experienced in.

The posterior and anterolateral (Watson Jones) approaches are more extensile in nature and may allow easier removal of the prior CMN. Furthermore, greater exposure of the femur with these approaches aids in the insertion of longer femoral stems which may be required. However, the majority of previous studies have utilized one of these two approaches and have concomitantly reported high complication rates [5, 8, 27]. Whether surgical approach plays a role in the elevated complication rate remains a topic of investigation.

There is a paucity of data regarding the use of the DAA during conversion THA; however, Gondusky et al. recently reviewed the role of this approach in conversion THA. The advantages of the DAA may include supine positioning of the patient and easier utilization of fluoroscopy. The use of the extensile DAA has been described which may allow complete access to the lateral femur. Disadvantages of the DAA in conversion THA include the inability to address abductor tendon pathology, possible need for multiple incisions to remove the CMN, and difficulty in addressing periprosthetic fractures [21].

Conversion THA is a technically demanding procedure and is associated with increased rates of complications. The surgeon needs to be aware of their ability and should factor in operative time, blood loss and his or her experience to individualize and optimize the planned approach [21].

Intraoperative considerations

Conversion THA can be a challenging procedure fraught with difficult dissection through distorted anatomy from the previous trauma and surgery which may be further complicated by heterotopic ossification, malunion or nonunion of the proximal femur. Winemaker et al. demonstrated the mean operative time for conversion THA was 95 min (±32.8) compared to 76.7 min (±26.1) for primary THA [33]. However, this included both patients treated with a SHS and those treated with a cannulated screw construct for proximal femur fractures. Numerous authors have demonstrated that conversion THA for failed intertrochanteric fractures is more difficult with a higher potential for complications which may increase the mean operative time for conversion THA [33–36].

Other studies have shown average operative times for conversion THA to be as high as 176 min, further signifying the complexity of these cases and the need for a well-designed preoperative plan [8, 18]. For challenging and time-consuming implant removal, consider a radiolucent table and imaging for difficult broken screw and hardware removal [18].

The removal of an intact CMN can be complex due to the presence of heterotopic bone, broken screws, or need to remove multiple locking screws [37]. Husain et al. demonstrated that for a titanium nail, average time for removal was 110 min compared to stainless steel nails which was on average 84 min [38]. The use of percutaneous guide wires, cannulated reamers to remove the heterotopic bone, and use of newer tapered femoral CMN extractors have allowed for removal of locked CMNs with less dissection and operative times of around 20–30 min (Fig. 3) [37, 39].

In addition to prolonged operating room times, conversion THA is associated with increased intraoperative blood loss and higher transfusion requirements [7, 8, 18, 33, 49]. Previous studies demonstrate an average estimated blood loss of 1300 mL during a conversion THA [7, 8, 18]. An allogenic blood transfusion carries a further risk of possible disease transmission, hemolytic transfusion reactions, transfusion related acute lung injury, increased length of stay, and cost [40]. Surgeons should attempt to minimize intraoperative blood loss during conversion THA with diligent hemostasis, use of tranexamic acid and correction of anemia preoperatively. Patients undergoing conversion THA might benefit from preoperative allocation of blood products and being made aware of the higher likelihood for transfusion or utilize cell saver technology [40]. In critical patients who refuse to receive blood transfusions, a technique whereby radiology floats an iliac balloon catheter to intermittently occlude blood flow thereby creating an "internal tourniquet" might be considered if the surgeon, anesthesia and radiologist are facile to complete this [41].

Complications

Many complications can occur during conversion of a failed CMN to hip arthroplasty. The complication rate of conversion THA is consistently higher than primary THA in the orthopedic literature and is reported to be as high as 47% [18, 36, 42]. The most common complication reported is fracture of the greater trochanter [8]. Other complications include instability, limb length discrepancy, heterotopic ossification, neurovascular complications, aseptic loosening, periprosthetic joint infection, and need for further revision surgery [8, 18, 43, 44, 50].

The greater trochanter may not be fully healed or can be fragmented during the hip arthroplasty which may impact postoperative abductor function. Zhang et al. reported that the majority of fractures occurred during reaming and broaching of the medullary canal [8]. Fractures of the greater trochanter may be the result of the large diameter hole created over the lateral proximal femoral cortex for the compression screw and could be worsened by clearing bony overgrowth off the screw in order to attach the extraction device. Fracture of the trochanter or dysfunction of the abductor mechanism could be one of the reasons that conversion THA has an increased dislocation rate [8].

The dislocation rate following conversion THA has been reported to range from 0 to 19.6%. Injury to the abductor mechanism, abductor insufficiency, poor bone quality, and reduced patient cognition are reported contributors for the increased rate of instability [45].

Antegrade cephalomedullary nailing requires perforation and penetration of the hip abductors which may also lead to substantial injury to these structures postoperatively. The rate of persistent trochanteric pain after antegrade CMN has been reported to be as high as 40% [46]. In one cadaveric study, McConnell et al. demonstrated that insertion of a CMN disrupted as much as 53% of the abductor tendon insertion [47]. Removal of the CMN and compression screw may lead to further hip abductor damage and, therefore, dysfunction. Thus, when removing a CMN, care should be taken to not further disrupt the abductor mechanism.

Periprosthetic joint infection following conversion THA has been reported to range between 6.2 and 9.1% [42, 49, 50]. In addition, possible is an increased superficial infection rate after conversion [42]. The increase in infection rate is likely due to a more extensile surgical approach necessary during a conversion procedure, longer operating room time, and the presence of prior hardware. Smith et al. also noted that patients who underwent conversion arthroplasty had increased comorbidities as measured via Charlson comorbidity index (CCI) which may also contribute. Given this increased risk of infection, a thorough preoperative workup is essential to rule out infection prior to conversion procedure. Additional interventions to mitigate the increased risk of infection such as use of vancomycin powder and povidone-iodine lavage should also be considered [51].

Conclusion

As the population ages, the number of extracapsular hip fractures will continue to increase dramatically. This trend will invariably result in increasing numbers of patients requiring arthroplasty following failure of CMN fixation. Because of this, it is critical that today's arthroplasty surgeons understand indications for conversion arthroplasty, implant selection, preoperative planning, surgical execution, and all possible perioperative and postoperative complications.

Patients have been shown to have good pain relief and functional improvements postoperatively. Implant survivorship following conversion THA has been reported to be as high as 97% at 7 years and 84.8% at 10 years with an end point of implant revision for any reason or radiographic evidence of implant loosening [19]. Despite these promising results, conversion THA has been demonstrated in multiple studies to be associated with increased costs, increased length of stay, higher blood loss, and more postoperative complications when compared to primary THA [48–50]. Thus, the dramatic increase in conversion surgery will have wide-ranging consequences to not only patient outcomes but the health care system at large.

Meticulous surgical technique for the index and conversion procedures is paramount in decreasing conversion surgeries and complications. Identifying unstable fracture patterns, selecting the correct implant, and performing an adequate reduction with proper CMN positioning are critical to minimizing the risk of screw cutout, nonunion, and malunion, especially in older, osteoporotic patients. Mitigation of complication risks requires thorough preoperative planning and meticulous execution of the conversion procedure. Careful soft tissue handling and implant selection facilitates accurate restoration of limb lengths, proximal femur offset, and healing.

The increase in hip fractures and CMN fixation will continue as our population ages. The need for conversion THA surgery following these procedures will similarly increase and present orthopedic surgeons with difficult THA conversions. A thorough understanding of the complexity of these cases and treatment is essential to patient outcomes now and into the future.

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Declarations

Conflict of interest CO certifies that he had nothing of value related to this study. JR certifies that he had nothing of value related to this study. BVM certifies that he had nothing of value related to this study. HM certifies that he had nothing of value related to this study. SL certifies that he had nothing of value related to this study. CC certifies that he had nothing of value related to this study. TB certifies that he had nothing of value related to this study.

Ethical approval The study has been performed in accordance with the ethical standards in the 1964 Declaration of Helsinki and has been carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA). This work was performed at The Albany Medical Center, Albany, NY.

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