A Stepwise Intraoperative Protocol to Minimize Complications after Volar Plating

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Abstract

Background Although outcome of volar plating is generally good, care should be taken to avoid specific iatrogenic and preventable complications, with an incidence reporting averaging 15%. Flexor tendon rupture due to a prominent plate, extensor tendon rupture due to a dorsal protruding screw tips, cartilage lesions due to intra-articular screw placement, loss of reduction due to insufficient stability, and persisting ulnar pain with distal radioulnar joint instability due to unstable triangular fibrocartilaginous complex lesions or unstable ulnar styloid base fractures all have been described.

Purpose We believe that a majority of these complications can be prevented by meticulous assessment of several intraoperative parameters during volar plating. Therefore, we introduce the WRIST protocol, a stepwise easy-to-remember manual that combines multiple fluoroscopic measurements to guide intraoperative decision making.

Conclusion Large prospective studies of the "WRIST" protocol are needed for validation. But we believe that it may help surgeons to optimize surgical technique, functional and radiographic outcome, and prevent complications when treating distal radial fractures.

Keywords
- distal radial fracture
- volar plate
- protocol
- complications

Open reduction and anatomical fixation with an anatomical volar locking plate has become the golden standard to treat distal radius fractures.[1–3] Although results are generally good, care should be taken to avoid specific iatrogenic and preventable complications. Incidence of these complications ranges from 14 to 18%.[4,5] Flexor tendon rupture due to a prominent plate, extensor tendon rupture due to a dorsal protruding screw tips, cartilage lesions due to intra-articular screw placement, loss of reduction due to insufficient stability, and persisting ulnar pain with distal radioulnar joint (DRUJ) instability due to unstable triangular fibrocartilaginous complex (TFCC) lesions or unstable ulnar styloid base fractures all have been described.[5–7]

We believe that a majority of these complications can be prevented by meticulous assessment of several intraoperative parameters during volar plating. Therefore, we propose to introduce the WRIST protocol that combines multiple fluoroscopic measurements to guide intraoperative decision making.

The WRIST Protocol

The protocol is also summarized in ►**Table 1**.

W = Wrist Anatomy

Treatment of distal radial fractures aims to restore normal anatomy to optimize clinical and functional outcomes.

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Table 1 Summary of the "WRIST" protocol

WRIST	Point of interest	Measurements
Wrist	Check wrist anatomy	Volar tilt, ulnar variance, articular step off
Range of motion	Perform full range of motion	Articular congruency, intra-articular screw tips
Instability	Check the fracture stability during provocative maneuvers	Volar rim, dorsal rim, capsuloligamentous lesions
Soong	Check the plate protrusion according to the Soong classification	Volar plate protrusion
TFCC	Check DRUJ ballottement stability and ulna	TFCC, ulnar styloid, and other associated lesions

Abbreviations: DRUJ, distal radioulnar joint; TFCC, triangular fibrocartilaginous complex.

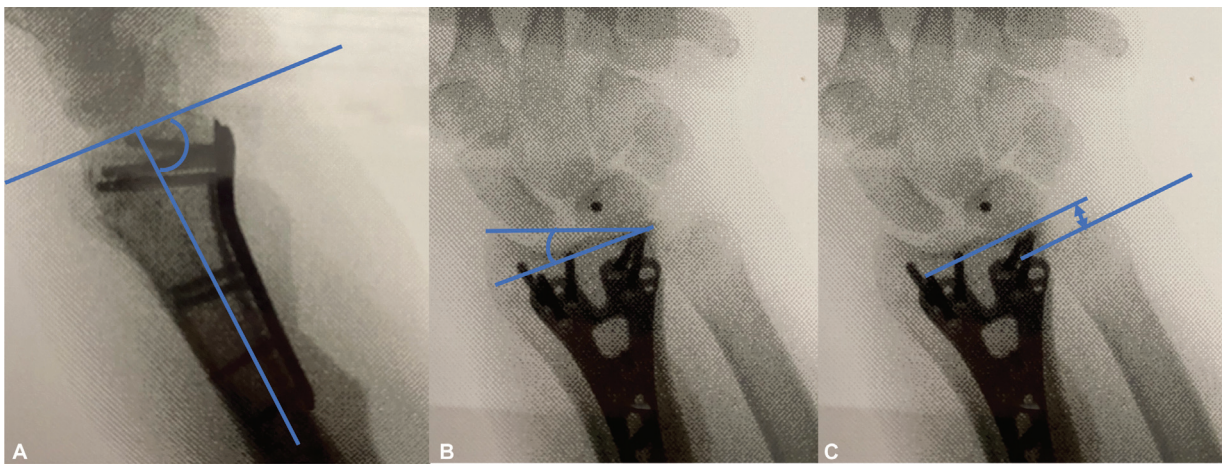

Fig. 1 (**A**) Measurement of volar tilt. (**B**) Measurement of radial inclination. (**C**) Measurement of ulnar variance.

Insufficient fracture reduction may result in short-term secondary displacement or long-term malunion, leading to secondary complications like adaptive carpal instability or ulnocarpal abutment syndrome.[8,9] To optimize radial anatomy, the following parameters should be assessed and properly restored: radial inclination, volar tilt, ulnar variance, and articular congruency (►**Fig. 1**). Dorsal tilt >-10 degrees, ulnar positive variance >2 mm, and articular step-off of >2 mm must be considered as insufficient and should be corrected.[10–12] These parameters can be assessed intraoperatively on an anteroposterior (AP) and lateral wrist view using fluoroscopy.

R = Range of Motion

Smooth and complete passive range of motion (flexion/extension, radial/ulnar deviation, and pronation/supination) should be obtained after fixation and tested under dynamic fluoroscopy if needed. If passive mobility is limited, active mobility will also be impaired. When crepitation or clicking is encountered, intra-articular screw position should be excluded.[13]

I = Instability

Static fluoroscopic assessment might fail to unveil residual instability. Fracture fixation stability can be tested using provocative mobilization maneuvers under dynamic fluoroscopy.[14,15] If a fracture fragment displaces under passive loading, there is insufficient plate or screw fixation stability. Volar rim instability can be tested by flexion in a lateral view, volar-ulnar corner instability by flexion in a volar oblique 45-degree view (►**Fig. 2**). Dorsal rim instability is tested by extension in a lateral view, dorso-ulnar corner instability by extension in a dorsal oblique 45-degree view, and the stability of the radial styloid by radial deviation in an AP view (►**Fig. 3**). Persistent fracture instability after plate fixation may result in loss of reduction during the healing process. Fragment-specific osteosynthesis using specially designed plate or screws can enhance fixation stability. For example, instability of the volar rim suggests that the plate must be placed more distally or fragment-specific rim plates must be used.[16,17] Insufficient dorsal rim stability can be managed by intraoperative conversion to longer screws, changing the direction toward the dorsal fragment, or adding dorsal implants like screws, pins, or plates.[18,19] Consequentially, if sufficient dorsal fracture stability is found after volar plating, this obliterates the need for extra dorsal fragment fixation (such as the "sandwich" technique).[20] Of course, preoperative computed tomography scan is often mandatory to provide indicative information to plan the surgery and which plate to use.

After fracture stability is attained, a displacement of the carpus relative to the radius must raise suspicion for radiocarpal capsuloligamentous lesions. If the carpus shifts ulnarly during a provocative ulnar shift maneuver, lesions

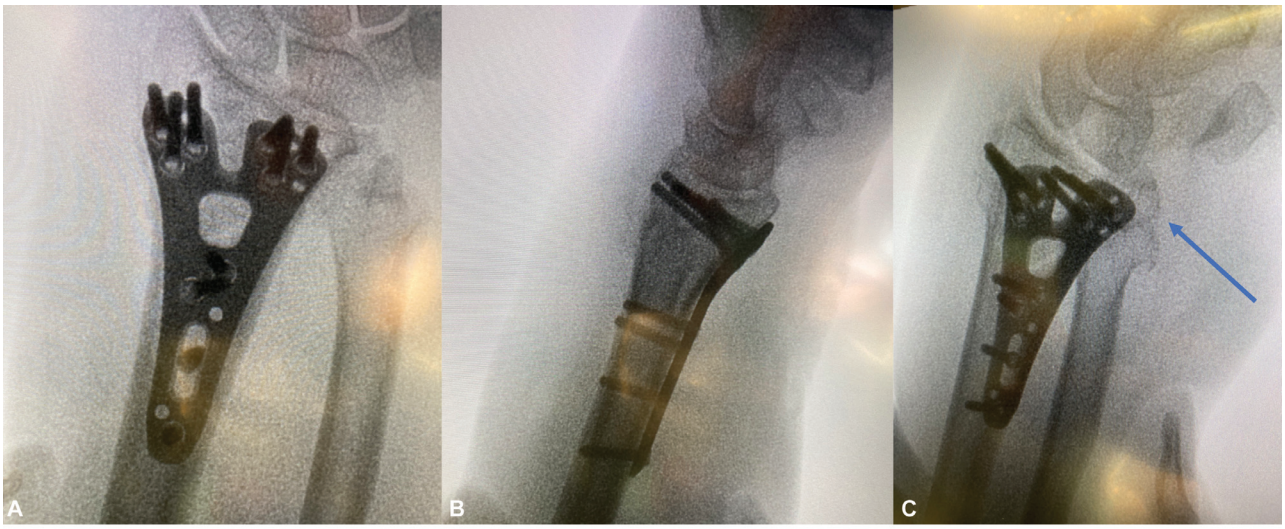

Fig. 2 (**A**) Anteroposterior view of volar plate for a volar Barton fracture. (**B**) Sagittal view volar plate for a volar Barton fracture. (**C**) Stable volar-ulnar fragment (arrow) due to plate buttressing when testing in flexion in a volar oblique 45-degree view.

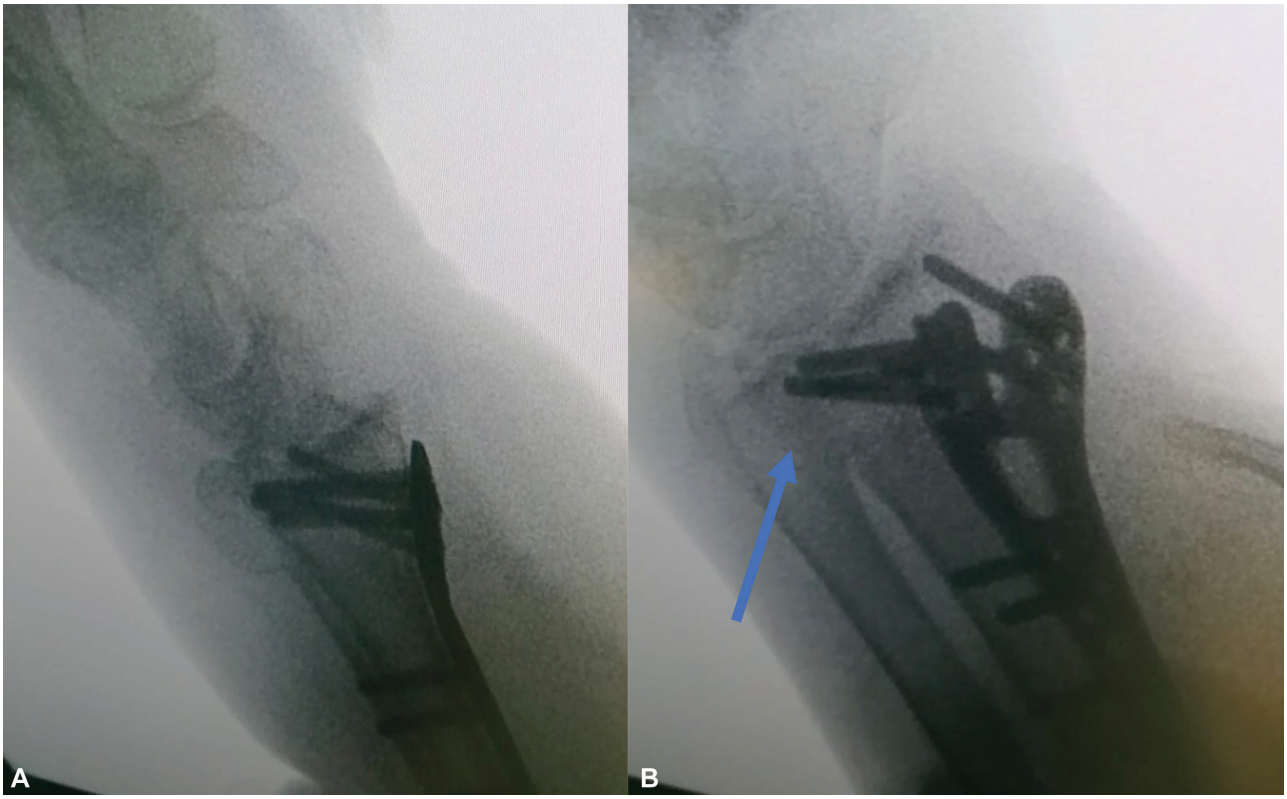

Fig. 3 (**A**) Displacement of the dorso-ulnar fragment after testing in extension in a sagittal view. (**B**) Stable dorso-ulnar fragment (arrow) due to sufficient screw length when testing in extension in a dorsal oblique 45-degree view.

to the radioscaphocapitate, short radiolunate, and/or long radiolunate ligament are present (►**Fig. 4**). If the carpus shifts volarly during a provocative volar shift maneuver, the capsular attachments (short and long radiolunate ligament) of the lunate are most likely still detached. Capsuloligamentous lesions can be addressed by capsuloligamentous sutures or rigid immobilization enhanced by radiocarpal pinning, radiocarpal plating, or bridging external fixator.[21,22]

S = Soong Classification

Soong et al published a classification that describes the relation of the most prominent part of the plate in relation to the watershed line, grading from less prominent to more prominent 0 to 2.[23] Later, they described how plate design, implant prominence, and inappropriate plate positioning might result in delayed flexor tendon rupture.[24] We advocate not only to assess the volar prominent plate edge projection, but also dorsal screw tip extrusion, with possible extensor

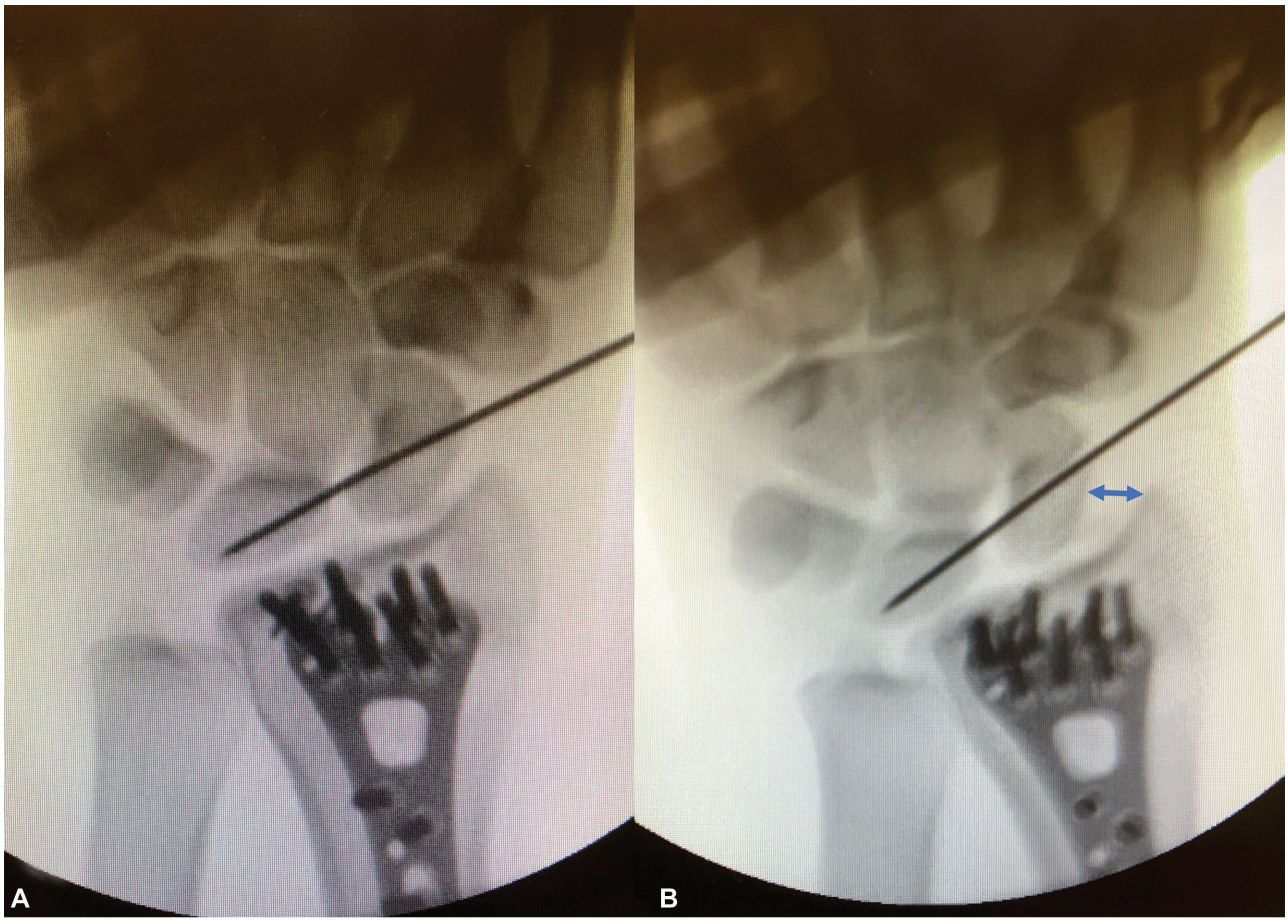

Fig. 4 (**A**) Anteroposterior view after volar plating and scapholunate pinning. (**B**) The carpus shifts ulnarly during a provocative ulnar shift maneuver.

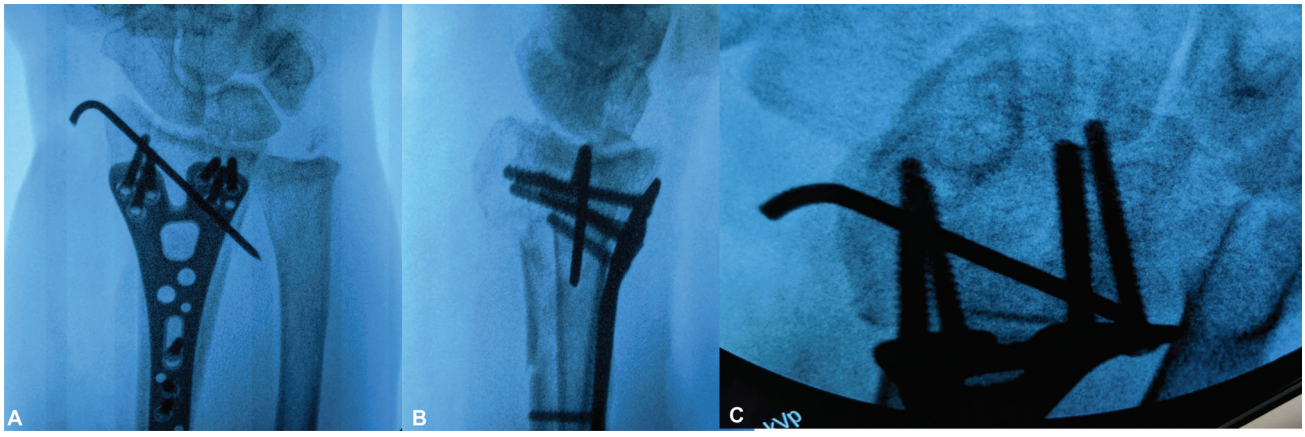

Fig. 5 (**A**) Anteroposterior view after volar plating. (**B**) Sagittal view after volar plating. (**C**) Skyline view after volar plating.

tendon conflict, on the lateral view and the skyline view (►**Fig. 5**).[25] If necessary, the volar plate should be reapplied with firm contact to the volar cortex of the distal radius.[26] A bicortical screw positioned in a distal row screw hole of the plate might aid in achieving optimal plate position and optimal plate-bone contact. The bicortical screw can be changed to an angle-stable screw at the end of the procedure. Fragment-specific plates may also reduce plate-tendon conflict.[27]

T = TFCC

As a final assessment, we propose inspection of the distal ulna and the stability of the DRUJ. The ballottement test of the DRUJ (AP translation) does not require fluoroscopy. A highly unstable ballottement test suggests instability of the DRUJ. This may be provoked by several reasons: articular incongruency of the DRUJ, radioulnar ligament injury, peripheral TFCC injury with inclusion of the foveal insertion, or an unstable ulnar styloid base fracture. The instability of the

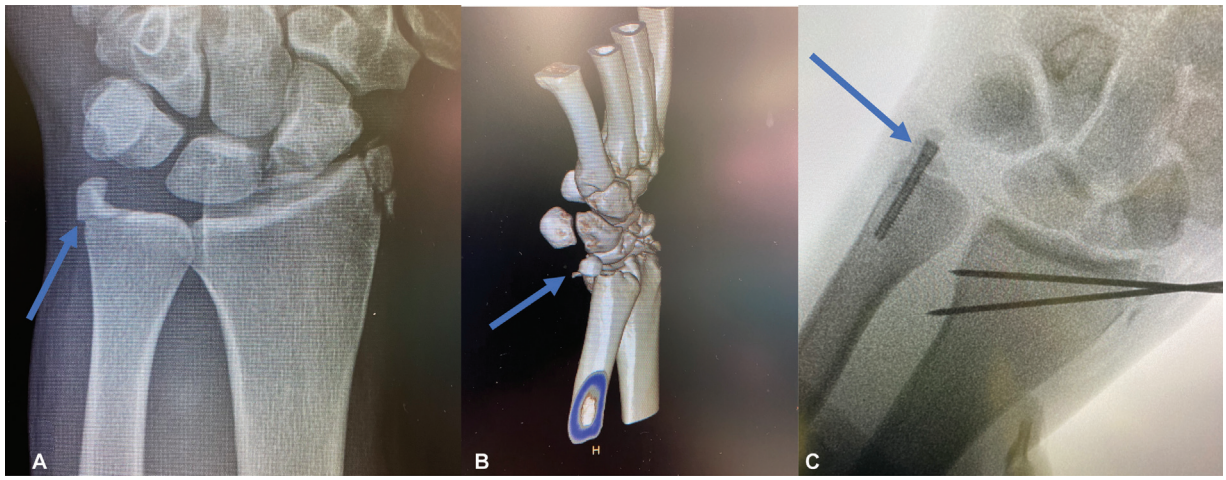

Fig. 6 (**A**) Ulnar styloid base fracture (arrow). (**B**) Displaced ulnar styloid base fracture (arrow) on computed tomography (CT) reconstruction. (**C**) Headless compression screw for an ulnar styloid base fracture (arrow).

DRUJ should be compared with the instability on the contralateral nonaffected wrist.[28] It is still under discussion whether TFCC injuries should be addressed immediately or during a secondary intervention if necessary.[29,30] However, in our experience, with sufficient wrist arthroscopy experience radioulnar ligament and TFCC injuries may be treated in the same time after addressing the distal radial fracture. Ulnar styloid base fractures are considered unstable if the displacement is >2 mm (►**Fig. 6**). Especially, in combination with a positive ballottement test, ulnar styloid base fractures should be fixed to prevent persistent DRUJ instability and/or nonunion of the ulnar styloid base which may become symptomatic. Several treatment options exist to fix the styloid base: tension band wiring, hook plate, pins, or headless compression screws.[31,32]

During wrist arthroscopy, other associated lesions like scapholunate lesions can also be assessed. The differentiation between acute and chronic scapholunate lesions, especially in the elderly, is sometimes challenging. Wrist arthroscopy enhances diagnostic accuracy. Treatment can be performed immediately with scapholunate pinning and/or capsuloligamentous suture.[33,34]

Discussion

We firmly believe that our stepwise WRIST protocol could drastically improve the quality of volar distal radius plating and reduce known complications. The protocol serves to primarily influence the intraoperative radiological outcome, which is known to not always correlate with the clinical and functional outcome. Large prospective studies of the WRIST protocol are needed for validation, to evaluate its user friendliness, and its effectiveness to reduce complications after volar distal radius plating. To our knowledge, currently no other authors have published an intraoperative guide to assess the necessity for additional dorsal plating during surgery.

In conclusion we believe that using our WRIST protocol may help surgeons to optimize surgical technique, functional and radiographic outcome, and prevent complications when treating distal radial fractures.

Authors' Contributions

- Conception of the protocol: C.K.G.
- Testing and reviewing of the protocol during surgery: C.K.G., G.V.E., N.D., K.V.R.
- Main writer of manuscript: C.K.G.
- Assisting writers of manuscript: G.V.E., N.D., K.V.R.
- Review of the submission: C.K.G., G.V.E., N.D.

All authors have met the ICMJE criteria for authorship.

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Conflict of Interest

None declared.

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