The use of a mobile software application to improve the management of open tibia fractures in a resource-constrained environment

Solomzi Mzamo,[1*] Jitesh Rajpaul,[2] Megan O'Connor,[3] John Arnold,[1] Leonard C Marais[4]

[1] Department of Orthopaedic Surgery, King Edward VIII Hospital, Nelson R Mandela School of Clinical Medicine, University of KwaZulu-Natal, Durban, South Africa
[2] Department of Orthopaedic Surgery, RK Khan Hospital, Nelson R Mandela School of Clinical Medicine, University of KwaZulu-Natal, Durban, South Africa
[3] Department of Orthopaedic Surgery, Inkosi Albert Luthuli Central Hospital, School of Clinical Medicine, University of KwaZulu-Natal, Durban, South Africa
[4] Department of Orthopaedic Surgery, School of Clinical Medicine, University of KwaZulu-Natal, Durban, South Africa

Corresponding author: solomzimzamo1@gmail.com

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Abstract

Background

The aim of the study was to compare the initial management and the outcomes of patients with open tibia fractures referred to a tertiary orthopaedic unit using a mobile software application (app), Vula Medical Referral (VULA), with those referred by handwritten referral letters (HWRL).

Methods

A retrospective analysis was performed on data collected from the clinical records of patients diagnosed with open tibia fractures and referred to a tertiary level orthopaedic trauma unit over two years. The referrals originated from a community health centre and a district-level hospital via electronic means (VULA) or physical referral letters (HWRL). The primary outcomes of interest included the initial patient management, the referral delay and definitive fracture management. Comparative complication rates within one year were an additional outcome of interest.

Results

One hundred and sixty-two cases were analysed, 103 (64%) in the VULA group and 59 (36%) in the HWRL group. The two groups displayed no significant differences in demographics or injury characteristics. There was a difference in the time from referral to the time of assessment at the tertiary centre ($p = 0.028$), with the VULA group having a shorter time (mean of 5 hours vs 6 hours). Differences were noted between the referral groups regarding referral documentation content, initial management strategies and complication rates. There were three (2%) patients with non-union and 17 (11%) with infection. The VULA group had comparatively fewer complications, 6% (6 of 103) compared to 24% (14 of 59) in the HWRL group.

Conclusion

This study found that using the VULA app resulted in better transfer of information and documentation of initial management of open fractures by the referring institution. Time from referral to being assessed by orthopaedics was also marginally better. While our findings suggest that there may be a lower complication rate with the use of the mobile application, further research is required to confirm this.

Level of evidence: Level 4

Keywords: open fracture, tibia, referral method, mobile application, software, technology

Introduction

Open fractures represent an orthopaedic emergency due to the risk of infection secondary to contamination, devitalised bone segments and compromised soft tissues.[1] The goals of open fracture management are fracture union, prevention of infection and restoration of function.[2,3] These goals are best achieved by prompt and appropriate early treatment and timely referral to a centre equipped with the necessary infrastructure and expertise required for definitive management.[4,5]

One of the essential principles in the initial management of open fractures is the early administration of intravenous antibiotics. It has been shown that a delay of more than three hours from injury to antibiotic administration was associated with a significantly higher infection rate.[6,7] In primary healthcare facilities, there is often a delay in administering prophylactic antibiotics. The possible reasons include a lack of resources, insufficient staff to cope with patient load or lack of knowledge about the significance of early antibiotic administration.[8,9] Apart from antibiotic therapy, fluid

resuscitation, the administration of tetanus toxoid, wound lavage, initial wound care and splinting of the involved limb are also vital in the immediate management of the patient.[10] It is well established that inadequate initial management and delay in the definitive management of open fractures may result in the need for more complex and time-consuming definitive treatment, increased cost to the healthcare system and poor outcomes for patients.[10,11]

Considering the above, the ideal referral platform would allow for open two-way communication between the primary and receiving healthcare providers to ensure optimal patient treatment.[12] Before the advent of sophisticated mobile software applications (apps), practitioners relied on telephonic discussion and generic hand-written referral letters (HWRL) to appropriately refer patients to a higher level facility. These documents may not contain all the necessary information needed for planning management of the patient, nor do they necessarily allow for knowledge transfer between care providers.

Apps such as VULA (software developer Mafami Pty Ltd) provide an alternative means of communication between healthcare professionals who work at different institutions and varying levels of seniority within our healthcare system.[13] The app allows for rapid access to specialist advice through a customisable discipline-specific online referral form that prompts the completion of pertinent questions on a mobile app interface (*Figures 1 and 2*). This user interface also provides for the exchange of vital multimedia such as X-ray images and clinical pictures of the patient's pathology (wound size, contamination and deformity).[9,14,15] One of the other advantages is that the referring doctor will not be able to proceed with submission of the referral without filling in essential mandatory fields.

The VULA app was gradually incorporated as part of the standard operating procedure for orthopaedic trauma and emergency referrals from primary healthcare facilities to regional and tertiary centres in KwaZulu-Natal.[12,14] The Protection of Personal Information Act (POPIA)-compliant app was initially developed for ophthalmology referrals in response to the challenges of rural healthcare access for ophthalmology patients in South Africa. VULA has since been expanded to over 16 specialities, each with a discipline-specific referral template for clinical information and images. In a study performed in Cape Town, the large volume of orthopaedic referrals received through the VULA app suggests that this technology represents a successful alternative to traditional referral methods.[14]

This study's main aims were to compare the initial management and the outcomes of patients with open tibia fractures referred to a tertiary orthopaedic unit using the VULA mobile app with those referred by HWRL. The specific outcome measures were the presence of complications (non-union and infection). Another study objective was the comparison of defined periods along the patient management pathway for the two referral methods.

Materials and methods

This observational, retrospective cohort study utilised the STROBE statement for reporting.[16] After obtaining the relevant ethical approval, a retrospective analysis of data collected from the clinical records of patients with open tibia fractures referred to a tertiary level orthopaedic trauma unit from 1 January 2018 to 31 December 2019 was performed. The admission lists of all orthopaedic patients during this period were obtained and patients with open fractures of the tibia identified. All VULA app referral data

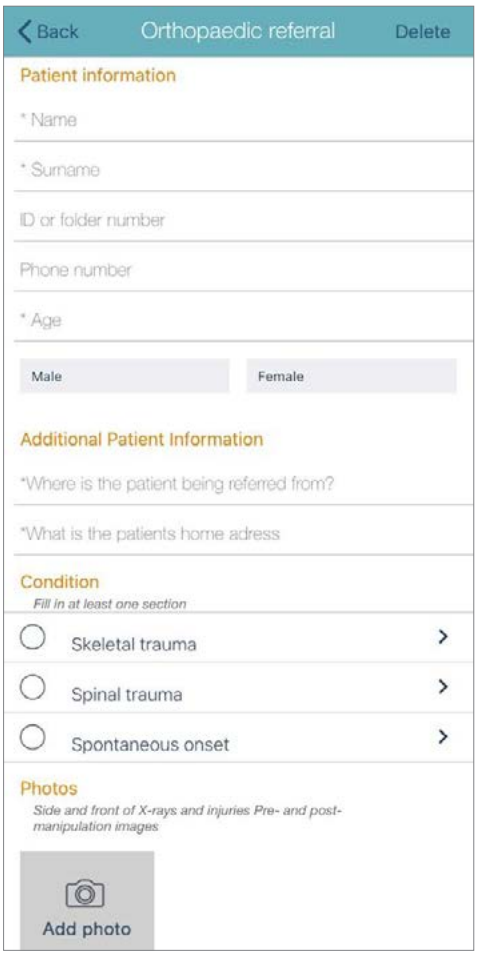

Figure 1. Screenshot of the VULA app orthopaedic referral user interface

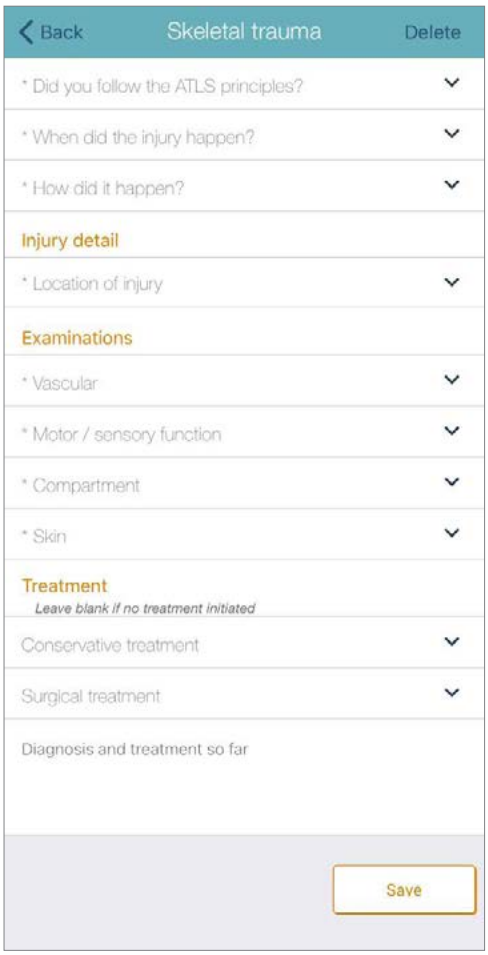

Figure 2. Screenshot of the skeletal trauma subsection user interface

during the study period were obtained from Vula Medical Referral (Mafami Pty Ltd) app data controllers. Patient demographic details and administrative data such as referral date, time and referring facility allowed for cross-referencing against the tertiary-level orthopaedic trauma unit records.

The inclusion criteria were the referral of all open tibia fracture patients from a community health centre (CHC) and a district-level hospital to a tertiary-level orthopaedic trauma unit over two years. Two groups of patients were then compared based on the referral method, namely the VULA group and the HWRL group. Records

Table I: Comparison of VULA-referred patients and the HWRL group in terms of baseline characteristics and outcome measures

Characteristic	VULA, n (%) [i]	HWRL, n (%) [i]	p-value[ii]
Number of patients	**103**	**59**	**–**
Demographics			
Age in years (median, IQR)	43 (24–59)	34 (25–47)	0.244 [iii]
Male sex	58 (56)	33 (56)	0.963
Referred from district hospital	55 (53)	31 (53)	0.916
Referred from community health centre	48 (47)	28 (47)	0.916
Comorbidities			
Hypertension	9 (9)	4 (7)	0.770
Diabetes mellitus	4 (4)	5 (8)	0.288
HIV	29 (28)	12 (20)	0.271
Respiratory disease	3 (3)	1 (2)	1.000
Associated injuries			
Bilateral/multiple open fractures	1 (1)	2 (3)	0.300
Multiple fractures (open and closed)	32 (31)	18 (31)	0.941
Shocked on admission	11 (11)	11 (19)	0.154
Head injury	9 (9)	7 (12)	0.521
Chest injury	4 (4)	2 (3)	1.000
Abdominal injury	7 (7)	8 (14)	0.153
Mechanism of injury			
Motor vehicle accident	19 (19)	15 (25)	0.294
Pedestrian vehicle accident	31 (30)	17 (29)	0.863
Assault	21 (20)	11 (18)	0.788
Fall	20 (19)	6 (10)	0.123
Complex gunshot (soft tissue loss)	7 (7)	7 (11)	0.269
Other	5 (5)	3 (5)	0.948
Site of open fracture			
Femur shaft	2 (2)	0 (0)	0.534
Distal femur	15 (15)	4 (7)	0.204
Proximal tibia	10 (10)	5 (8)	1.000
Tibial shaft	37 (36)	27 (46)	0.218
Distal tibia	27 (26)	14 (24)	0.726
Ankle	11 (11)	5 (8)	0.787
Humerus	1 (1)	3 (5)	0.138
Patella	0 (0)	1 (2)	0.364
Gustilo-Anderson grade			
Grade 1	18/100 (18)	10/59 (17)	0.867
Grade 2	42/100 (42)	27/59 (46)	0.644
Grade 3A	26/100 (26)	14/59 (24)	0.750
Grade 3B	14/100 (14)	8/59(14)	0.938
Complications			
Infection	4 (4)	13 (22)	**0.001**
Non-union	2 (2)	1 (2)	1.000
Follow-up in months (median, IQR)	12 (6–24)	12 (6–24)	0.591 [iii]

i) Denominator equal to number of patients in the group (n=103) unless stated otherwise; ii) Fischer exact or chi² tests unless stated otherwise; iii) Mann-Whitney test.
IQR: interquartile range

for patients of all ages, ethnicities and sexes were included. Four patients were excluded from the study as three had incomplete medical records (missing pages from the patient folder), and one was lost to follow-up. The data regarding the time to antibiotic administration was not recorded by the clinicians in both the HWRL and VULA groups.

Patient demographics, comorbidities, the location of the open fracture, associated injuries, mechanism of injury, open-fracture grading (Gustilo-Anderson classification[17]) done at the time of debridement, time from injury to referral, time from referral to assessment at the tertiary centre, initial management at the referring centre, and complications encountered were extracted from records and captured on a Microsoft® Excel spreadsheet, version 16.59 (© 2022 Microsoft. All rights reserved). Stata/IC version 15.0 (© StataCorp LLC) was used to analyse the data. A p-value < 0.05 was considered statistically significant. Categorical predictors were compared between the two groups using chi-square or Fisher's exact tests as appropriate. Time from injury to referral, time from referral to assessment at the tertiary centre, and total time from patient presentation to initial evaluation at the tertiary centre were expressed as medians with interquartile range (IQR) and compared using Mann-Whitney hypothesis tests for non-parametric data.

Results

One hundred and sixty-two patients were analysed, 103 (64%) in the VULA group and 59 (36%) in the HWRL group. The demographics and fracture characteristics of the two groups are shown in *Table I*. There were no significant differences between the groups regarding age, sex or referring site. Pedestrian vehicle accident (PVA) was the most frequent mechanism of injury for both groups, 30% (31 of 103) in the VULA group and 29% (17 of 59) in the HWRL group. Similarly, in both groups, most fractures were located in the tibial shaft, 36% (37 of 103) in the VULA group and 46% (27 of 59) in the HWRL group, respectively. The most common open-fracture grading score for both groups was Gustilo-Anderson grade 2 injuries. There were no significant differences between the groups for mechanism, fracture location or open-fracture grading. The follow-up period was also the same in the two groups, with a mean of 12 months (range 6–24).

A comparison between the two groups with regard to documentation, initial management by the referring doctor, and defined periods is outlined in *Table II*. There were statistically significant differences (p < 0.001) between the referral groups regarding all documentation characteristics except the recording of comorbidities. The VULA group consistently had more complete data such as the name of referring and receiving doctors, mechanism and time of injury, and associated injuries (all recorded 100% of the time). In addition, average times for defined periods are reported for each group. These include the median time from injury to referral, the mean time from referral to assessment by an orthopaedic team member at the tertiary centre, and the median total time from injury to assessment at the tertiary hospital. Notably, there was no statistical difference between the groups for the time from injury to the patient presentation (median 24 hours, IQR 6–72 hours for both groups, p = 0.962) or the total time from injury to assessment at the tertiary centre, 30 hours (11–75 hours) for the VULA group and 53 hours (11–76 hours) for the HWRL group (p = 0.547). However, there was a statistically significant difference in time from referral to assessment at the tertiary centre (p = 0.028), with the VULA group having a shorter mean time of 5 hours (SD ± 1.56 hours) compared with 6 hours (SD ± 1.49) in the traditional HWRL group.

Two per cent of patients (3 of 162) developed a non-union, and 11% (17 of 162) complicated with an infection. One per cent

Table II: Comparison of VULA and HWRL groups in terms of documentation, initial management by referring physician and defined periods of time

Characteristic	VULA, n (%)	HWRL, n (%)	p-value [i]
Number of patients	**103**	**59**	**–**
Documentation			
Name of referring physician recorded	103 (100)	31 (64)	**< 0.001**
Name of receiving physician recorded	103 (100)	39 (66)	**< 0.001**
Mechanism of injury recorded	103 (100)	37 (63)	**< 0.001**
Time of injury recorded	103 (100)	21 (36)	**< 0.001**
Associated injuries recorded	103 (100)	19 (32)	**< 0.001**
Comorbidities recorded	42 (41)	17 (29)	0.128
Initial management by referring physician as documented			
Neurovascular examination recorded	103 (100)	19 (32)	**< 0.001**
Irrigation of the wound	103 (100)	19 (32)	**< 0.001**
Wound covered with saline gauze dressing	82 (80)	49 (83)	0.592
Limb re-alignment and splinting	103 (100)	19 (32)	**< 0.001**
IV antibiotics given	103 (100)	38 (64)	**< 0.001**
Tetanus prophylaxis given	103 (100)	38 (64)	**< 0.001**
X-rays provided (image or film attached)	103 (100)	19 (32)	**< 0.001**
Time in hours			
Time from injury to referral (median, IQR)	24 (6–72)	24 (6–72)	0.962 [ii]
Time from referral to assessment by orthopaedics at tertiary centre (mean ± SD)	4.98 (± 1.56)	5.53 (± 1.49)	**0.028** [iii]
Total time from injury to assessment by orthopaedics at tertiary centre (median, IQR)	30 (11–75)	53 (11–76)	0.547 [ii]

i) Fischer exact or chi² tests, unless stated otherwise; ii) Mann-Whitney test; iii) Student t-test, values in bold determined to be statistically significant.
IQR:– interquartile range; SD: standard deviation

Table III: Cross tabulation depicting the presence of complication based on a 12-hour time to referral cut-off

		Complication (non-union or infection)		
		No Count (%)	Yes Count (%)	Total Count (%)
Time to referral*	< 12 hours	58 (88)	8 (12)	66 (100)
	≥ 12 hours	85 (89)	11 (12)	96 (100)
	Total	143 (88)	19 (12)	162 (100)

* Time to referral represents the total time from injury to first assessment at the tertiary centre; % = percentage

Table IV: Cross-tabulation depicting the presence of complications comparing the referral methods

		Complication (non-union or infection)		
		No Count (%)	Yes Count (%)	Total Count (%)
Referral method	HWRL group	45 (76)	14 (24)	59 (100)
	VULA group	98 (95)	5 (5)	103 (100)
	Total	143/161 (88)	19/161 (12)	162 (100)

% = percentage

(1 of 162) of patients had both a non-union and an infection. A delay in referral of more than 12 hours was seen in 59% (96 of 162) of patients. A cross-tabulation between the timing of referral and complications is shown in *Table III*. Of those patients with a delay of fewer than 12 hours, 12% (8 of 66) experienced a complication. The same percentage of complications were experienced by patients with a delay of more than 12 hours, namely 12% (11 of 96), demonstrating that the timing of referral from the injury sustained was not associated with an increased complication rate ($p = 0.677$).

A similar cross-tabulation (*Table IV),* comparing referral method and complication rates, demonstrated a statistically significant association between using the VULA app and a reduced complication rate. Of the traditional HWRL group, 24% (14 of 59) experienced complications, whereas, in the VULA group, 5% (5 of 103) experienced complications ($p < 0.001$). The relative risk of complications in the HWRL group compared with the VULA referral group was 4.97 (95% CI, 1.89–13.11).

Discussion

This study aimed to determine if using a digital mobile application improved the initial management of open fractures, enhanced the efficiency of patient transfer and ultimately reduced the complications commonly associated with open fractures of the tibia.

One of the advantages of using a mobile app interface is the customisation of the referral template, which can be tailored according to the various pathologies encountered by a specific medical speciality (*Figure 2*). In the case of skeletal trauma, different management principles must be followed at a primary healthcare level to ensure that the patient is less likely to develop complications such as non-union of bone or osteomyelitis. While many of these management principles are carried out by the referring practitioner by following protocols, it is not always documented. It is essential for the receiving doctor to be made aware of the patient's initial management and to advise the referring doctor of any critical steps that need to be taken. Another major stumbling block in the patient referral pathway is the delay that occurs while telephonically attempting to refer patients between institutions via a manual switchboard system. Dropped telephone calls, poor network quality and incorrect contact details can delay patient transfer and cause further frustration for the busy healthcare worker in an emergency casualty setting.

An analysis of the data comparing our two patient groups showed a significant difference in the documentation of the patient's initial management and the referral letter's specific content. Due to the high burden of trauma, shortage of healthcare workers and the lack of electronic medical records in our public healthcare system, note keeping, documentation of injuries and handwritten referral letters often contain very sparse, incomplete information. While we cannot determine whether the initial management of patients was more complete in either group, the study's findings indicate that the documentation in the VULA group referrals contained significantly more detailed information about patient management, which was likely to have benefitted both the healthcare practitioners and the patient. This two-way exchange of information may also have improved the coordination of care between the primary care facility and the tertiary care hospital, as has been the finding in a previous study.[14]

Regarding the initial management, all patients referred using the VULA app had documented evidence of receiving an initial dose of intravenous antibiotics, tetanus prophylaxis, wound irrigation, splinting of the limb and appropriate imaging. In the HWRL group the above essential management steps were only documented in 32–64% of patients. These findings are concerning as a delay in administering intravenous antibiotic therapy is predictive of increasing infection rates in open fractures.[6,13,18] In the absence of prophylactic antibiotic administration, an infection can occur in 20% of patients with open fractures.[3,6,19] In the HWRL group, documentation regarding intravenous antibiotic therapy was only recorded in 64% (38 out of 59) of patients. We are unable to determine whether antibiotics were administered in the remainder; however, it is notable that this group had a higher infection rate.

Concerning time periods, our study showed a statistically significant difference in the time from a referral at the base hospital to patient assessment at the tertiary hospital ($p = 0.028$), with the VULA group having a shorter time (median of five hours compared with six hours in the HWRL group). The reduced time may be attributed to the fact that the referring doctor had quicker access to the doctor on call at the receiving institution via the VULA app interface, compared to a telephonic discussion via a manual switchboard. The workflow of referring a patient on the VULA app involves selecting the relevant hospital, specialist department and the doctor on duty. The patient information is entered, X-ray images are transferred promptly via mobile data, and the referral doctor awaits a response. Our findings demonstrate that this method of communication is more efficient than the traditional referral method, and may impact the delay in access to theatre and initial surgical management where initial debridement is one of the most significant predictors of infection in open fractures.[7,13,18] Hull et al. stated in their paper that every hour of delay to debridement was associated with an increase in the likelihood of infection, which was more remarkable for fractures of the tibia, with higher Gustilo-Anderson grading and in those grossly contaminated open injuries.[10,11]

Lastly, comparing the referral method and complication rates, we found a statistically significant association between using the VULA app and reducing complications. This is despite the VULA group comprising an older cohort (nearly ten years older) and a greater percentage of comorbidities (although this did not reach significance), which may have minimised the actual reduction observed.

This study had several limitations. Being retrospective, other factors affecting open fracture outcomes, such as removal of gross contamination and definitive wound management, were not consistently reported in the patient records and could not be

included in the analysis. While documentation in the HWRL group was missing vital information, we are unable to determine whether the letter was augmented with a telephonic discussion between practitioners, which may have included information about some of the missing management steps in the letter. Despite these limitations, we have shown that apps such as VULA can provide an effective, alternative means of communication between healthcare professionals based at peripheral and central hospitals.

This technology shows promise in allowing for rapid access to specialist advice with the potential to timeously address known predictors of poorer open fracture outcomes and decrease complication rates. Further research on the use of this technology can focus on whether doctors at the referring institution benefit from the knowledge transfer that is provided by the two-way exchange on the VULA application (upskilling). Research also needs to be done on whether, from a doctor's perspective, it is a more efficient and user-friendly alternative to communicate with a practitioner at a referral hospital specialist unit compared to traditional methods.

Conclusion

This study found that using the Vula Medical Referral (by Mafami Pty Ltd) mobile software application resulted in better transfer of information and documentation of initial management of open fractures by the referring institution. Time from a referral at the primary facility to being assessed by a team member from the orthopaedic unit at the tertiary facility was also marginally better. While our findings suggest that there may be a lower complication rate with the use of the mobile application, further research is required to confirm this.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.
Prior to commencement of the study ethical approval was obtained from the following ethical review board: University of KwaZulu-Natal and BREC/00001059/2020.
All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.
Informed written consent was not obtained from all patients for being included in the study, as this was a retrospective study.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

SM: contributed to design, data collection, and manuscript preparation
JR: contributed to conceptualisation, design and manuscript review
MOC: contributed to manuscript preparation
JA: contributed to conceptualisation
LCM: contributed to data analysis, statistical analysis and manuscript preparation

ORCID

Mzamo S https://orcid.org/0000-0002-3122-1979
Rajpaul J https://orcid.org/0000-0001-8950-4878
O'Connor M https://orcid.org/0000-0001-8864-4916
Arnold J https://orcid.org/0000-0002-8295-8444
Marais LC https://orcid.org/0000-0002-1120-8419

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