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Internal carotid artery calcifications in a South African population: A CBCT imaging study

André Uys[1] | **Diana Mavuso**[2]

[1]Department of Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa

[2]Department of Oral Pathology and Oral Biology, School of Dentistry, Faculty of Health Sciences, University of Pretoriaa, Pretoria, South Africa

Correspondence
André Uys, Department of Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, Corner of Dr. Savage and Bophelo road, 0001 Pretoria, South Africa.
Email: andre.uys@up.ac.za

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Abstract

Background: Stroke is the second leading cause of death globally and account for 25,000 deaths annually in South Africa. Both medial and intimal located intracranial internal carotid artery (iICA) calcifications are associated with stroke. Cone beam computed tomography (CBCT) is commonly used where advanced dental imaging of the skull is required and often includes areas outside of the field of interest. Modalities such as CBCT have great potential to identify and provide early detection of calcifications during imaging for dental purposes. The aim of the study was to investigate the presence, distribution and extent of iICA calcifications in a South African population using CBCT images. Retrospectively collected CBCT data sets of 582 patients were evaluated. All data sets were evaluated for the presence, location and severity of calcifications within the course of the internal carotid artery.

Results: Age was associated with a higher prevalence of internal carotid artery (ICA) calcifications, but sex was not. Individuals older than 61 years presented with a high number of calcifications. In total, the presence of calcifications was found in 199 patients (i.e. 34.19% of the patients). White South African individuals showed the highest prevalence. A higher degree of calcifications was also present within the C4, C5 and C6 ICA segments.

Conclusions: Detection of calcifications along the course of the ICA was possible using CBCT images taken for dental treatment purposes. Early detection of calcifications allows for appropriated referral and assessment which will be beneficial to the patient presenting with ICA calcifications.

KEYWORDS
CBCT, internal carotid artery calcifications

1 | INTRODUCTION

Stroke is the second leading cause of death globally and account for 25,000 deaths annually in South Africa[1,2]. The burden of stroke is on the increase due to sociodemographic and lifestyle changes[3]. Imaging studies have demonstrated that intracranial internal carotid artery calcific atherosclerotic lesions can be the cause of stroke in older patients[4]. Both medial and intimal located intracranial internal carotid artery (iICA) calcifications are associated with stroke[5]. Furthermore, it was found that intracranial artery calcifications were a very common finding in memory clinic patients[5].

Cone beam computed tomography (CBCT) is commonly used where advanced dental imaging and diagnosis of the skull is required. As such, the larger field of view images

Abbreviations: BSA, Black South African; ExCICA, extracranial internal carotid artery calcification; InCICA, intracranial internal carotid artery calcification; WSA, White South African.

often includes areas outside of the field of interest[6]. Cone beam computed tomography has shown that it can detect delicate structures which is comparable to multi-detector computed tomography (MDCT)[7].

Based on the above, the presence, distribution and extent of iICA calcifications have not been investigated in a South African population. This study aimed to evaluate retrospectively the prevalence, severity and distribution of iICA calcifications along the segments of the internal carotid artery using CBCT scans in a South African population. More invasive techniques will always remain vital for the diagnosis and treatment of significant stenotic vessels but modalities such as CBCT have great potential to identify and provide early detection during imaging for dental purposes.

2 | METHODS

The study was a retrospective cross-sectional design study carried out in the Department of Oral Pathology and Oral Biology, School of Dentistry, University of Pretoria, in the section of Diagnostic Imaging. It was conducted on CBCT images taken for the purposes of general dental treatments. All scans were acquired by a single CBCT unit (Planmeca Promax 3D Max; Planmeca OY). The CBCT unit's resolution ranged from 100 to 400 μm, with 300 to 750 basic frames. The anode current used ranged from 1 to 14 mA and anode voltage ranged from 54 to 90 kV, with a focal spot diameter of 0.6 mm.

A total of 582 CBCT image data sets meeting the inclusion criteria were evaluated. The inclusion criteria included all individuals older than 30 years of age of which the CBCT image included the internal carotid artery (ICA) segments. Demographic data and medical history were obtained from the hospital patient files. All assigned demographic data were made according to self-classification information present in the patient's hospital records. The study included 378 males and 204 females and the patients were divided into five age groups as well as into three population groups (Table 1).

All CBCT data sets were evaluated for the presence and location of calcifications within the course of the ICA. The severity was evaluated according to a visual scale for the description of the calcifications (Figure 1). The course of the ICA was segmented into the cervical portion (C1), petrous portion (C2) and lacerum segment (C3) which is the area above foramen lacerum, cavernous segment (C4) the portion that ascends towards the posterior clinoid process and passes forward by the side of the body of the sphenoid bone, and then curves upward on the medial side of the anterior clinoid process. The other two segments include the clinoid segment (C5) and the ophthalmic segment (C6).

All CBCT planes were examined for the presence of calcifications. The first and second authors were calibrated and examined all the data sets independently. Each examiner evaluated all the selected scans to investigate the prevalence, distribution and degree of severity of calcification along the segments of the ICA. After the evaluation, all the results were compared and conflicting results were re-evaluated until consensus was reached. In addition, a third dentist with experience in maxillofacial radiology, independently randomly evaluated 30 CBCT scans to determine inter-examiner reliability.

CLINICAL RELEVANCE

Scientific rationale for study

The importance of evaluating, and recognizing important pathological findings when requesting a cone beam computed tomography (CBCT) scan for clinical purposes is highlighted. The study evaluated the degree of calcifications along the segments of the internal carotid artery related to age, sex and population group on CBCT scans.

Principle findings

Individuals older than 61 years presented with a high number of calcifications with white South African individuals showing the highest prevalence. A higher degree of calcifications was present within the C4, C5 and C6 ICA segments.

Practical implications

Patients with established risk factors presenting with iICA calcifications should be referred to physicians for further investigation and imaging.

3 | RESULTS

In total, the presence of calcifications was found in 199 patients (i.e. 34.19% of the 582 patients included in the study), this number is inclusive of patients having both intracranial, extracranial calcifications which may present unilaterally and/or bilaterally. With respect to where the calcifications were positioned, 198 (34.88%) patients presented with iICA calcifications, with five patients (of the 198) having both extra- and intracranial calcifications, and one patient (0.17%) with only bilateral extracranial calcifications (Figure 2). Of the 199 patients with calcifications, 116 patients were Black, 73 were White and 10 were Indian. These figures are presented in Table 1 and Figure 3 where each calcification present was allocated to each population, sex and age group.

With regard to the frequency and severity within the different segments of the ICA an increase is seen for severe and moderate calcifications for segments C3–C6 (Figures 4 and 5).

4 | DISCUSSION

The study found that calcifications related to the ICA can be identified on CBCT data sets taken for routine dental

TABLE 1 Population, age and sex groups for the presence of calcifications

Population group	Age groups (in years)	Sex	Total patients for each group	The absence of calcifications	ExCICAUnilateral	bilateral	InCICAUnilateral	bilateral
BSA individuals	30–40	F	54	47 (87%)	1	0	6	0
		M	104	84 (80%)	1	0	19	0
	41–50	F	43	36 (83%)	1	1	4	1
		M	86	75 (87%)	1	0	3	7
	51–60	F	24	15 (62%)	0	0	2	7
		M	44	27 (61%)	0	0	6	11
	61–70	F	17	3 (17%)	0	0	5	9
		M	16	5 (31%)	0	1	4	6
	71+	F	12	2 (17%)	0	1	3	6
		M	13	3 (23%)	0	0	1	9
WSA individuals	30–40	F	4	4 (100%)	0	0	0	0
		M	16	11 (69%)	0	0	2	3
	41–50	F	18	18 (100%)	0	0	0	0
		M	24	16 (67%)	1	0	5	2
	51–60	F	14	6 (43%)	0	0	3	5
		M	8	3 (38%)	0	0	2	3
	61–70	F	18	8 (45%)	0	0	1	9
		M	20	3 (15%)	0	1	2	14
	71+	F	10	3 (30%)	0	0	2	5
		M	14	1 (0.07%)	0	1	1	11
Indian individuals	30–40	F	5	5 (100%)	0	0	0	0
		M	6	5 (83%)	0	0	0	1
	41–50	F	2	2 (100%)	0	0	0	0
		M	1	0 (0%)	0	0	0	1
	51–60	F	0	0 (0%)	0	0	0	0
		M	1	1 (100%)	0	0	0	0
	61–70	F	0	0 (0%)	0	0	0	0
		M	3	0 (0%)	0	1	1	1
	71+	F	1	0 (0%)	0	0	0	1
		M	4	0 (0%)	0	0	1	3
Total			582	383	5	6	73	115

treatment. The presence, location and severity could be assessed for our study population.

By means of logistic regression analyses, we found that age was associated with a higher prevalence of ICA calcifications, but sex was not. The frequency of calcifications within the ICA increased with age, with individuals older than 61 years of age presenting with a higher number of calcifications than without. Our results corresponds to a study by Kockelkoren et al.[8] who found that the prevalence of ICA calcifications gradually increases with age and that after the age of 70 years virtually all patients will be affected. The prevalence of calcifications between population groups was also different, with White South African individuals showing the highest prevalence followed by the Indian population and then the Black population. Sociodemographic and lifestyle changes can be the reason for the population differences. In a study by Ranganai and Matizirofa[9] predictors significantly associated with an increase likelihood of stroke were heart problems, diabetes, female sex, age 59–98 years and a white ethic group.

A higher degree of calcifications was present within the C4, C5 and C6 segments. This result corresponds to

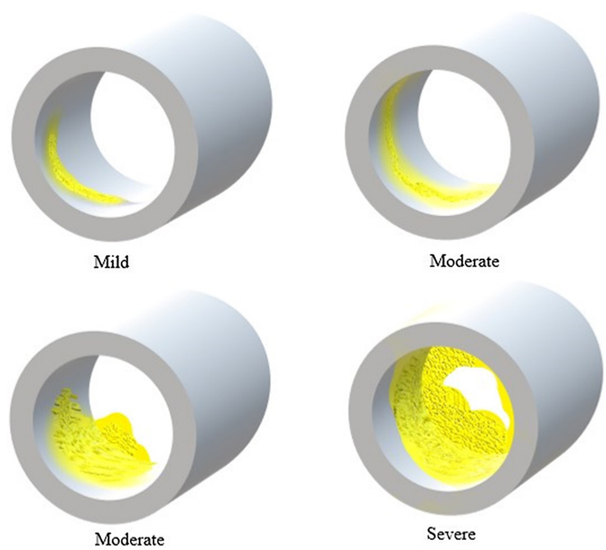

FIGURE 1 Severity of calcification patterns within the internal carotid artery lumen: Mild (thin and discontinuous); moderate (thin and continuous or thick and discontinuous); or severe (thick and continuous)

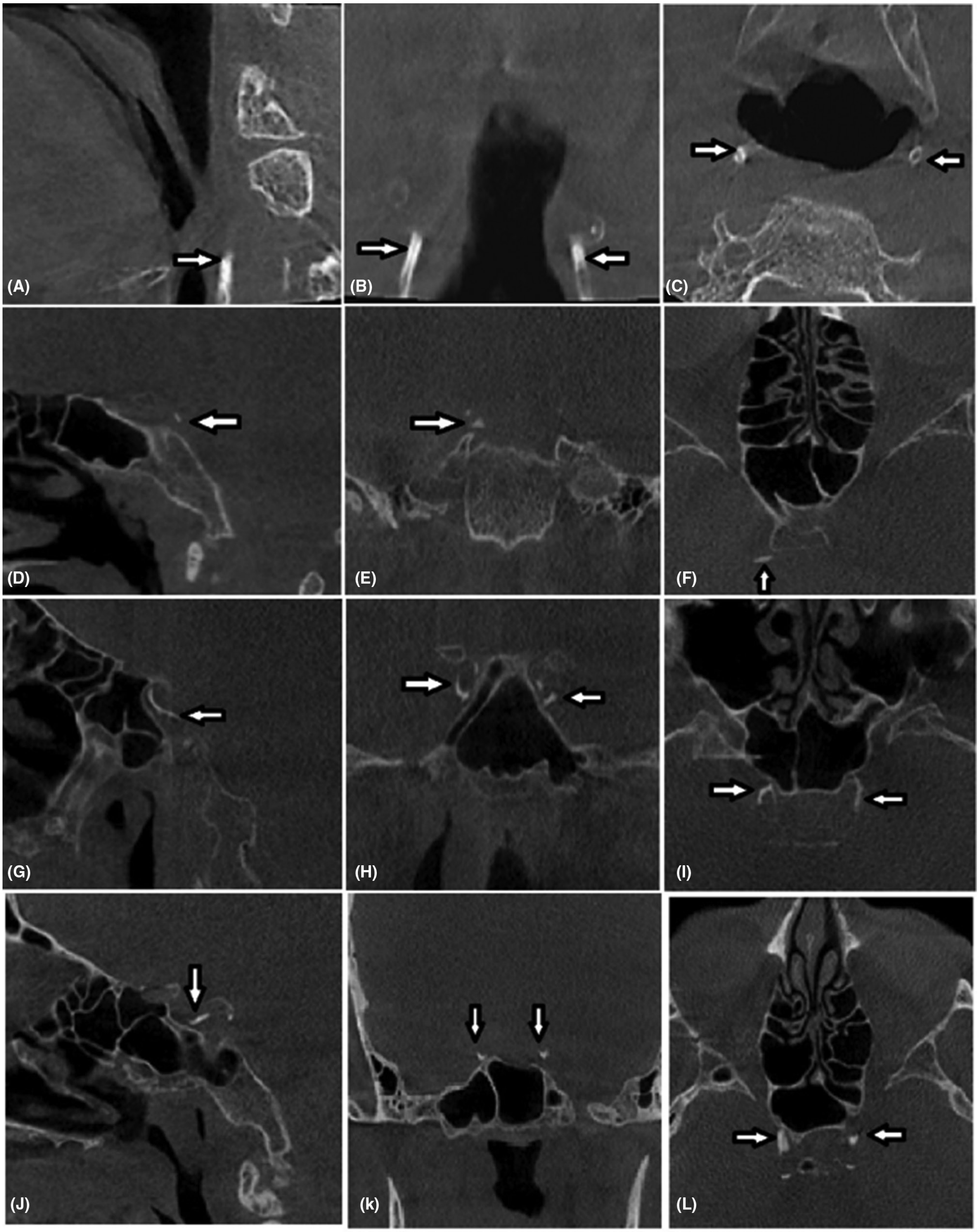

FIGURE 2 Examples of the different degrees and locations of calcifications on cone beam computed tomography images. (A)–(C) demonstrates calcifications at the cervical segment of internal carotid artery (ICA) in a 66-year-old male. (D)–(F) demonstrates calcifications at the ophthalmic segment of ICA in a 49-year-old male. (G)–(I) demonstrate calcifications at the cavernous segment of ICA in a 66-year-old female. (J)–(L) demonstrate calcifications at the clinoid segment of ICA in a 58-year-old female

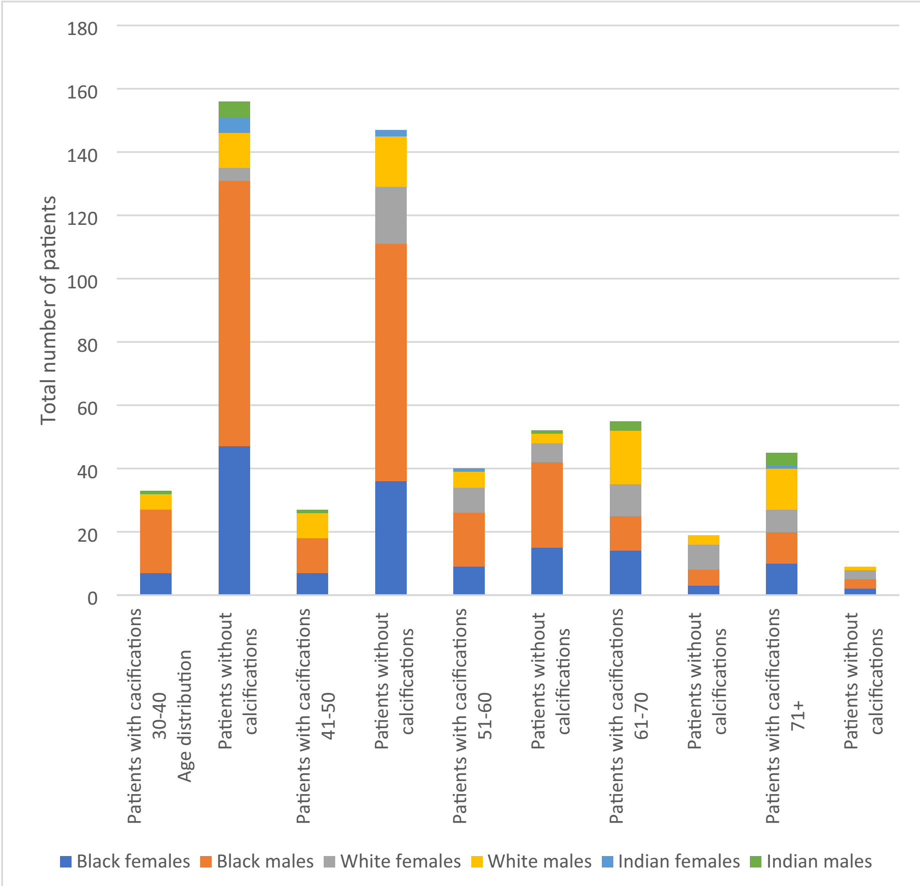

FIGURE 3 Distribution of age of the cohort differentiated by sex, population group and the presence of calcifications for the whole cohort

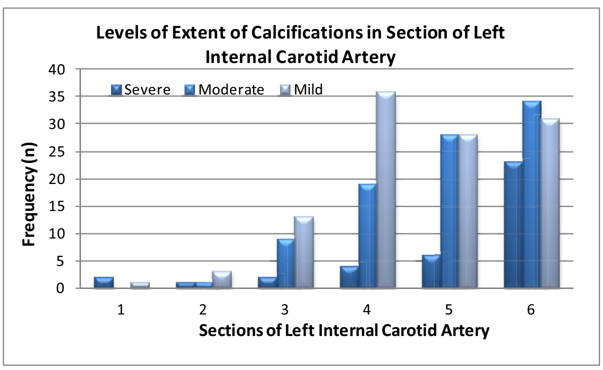

FIGURE 4 Frequency distribution of calcifications within the segments of the left internal carotid artery for all population and sex groups combined

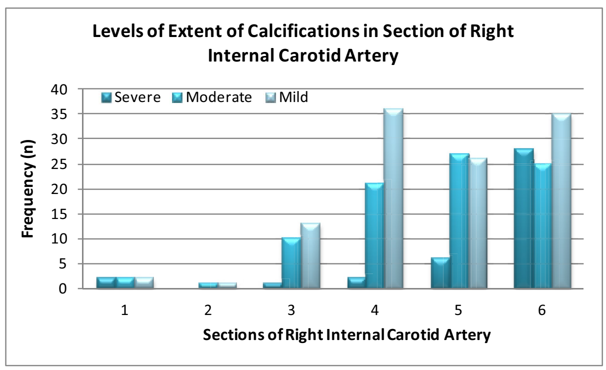

FIGURE 5 Frequency distribution of calcifications within the segments of the right internal carotid artery for all population and sex groups combined

similar studies either using different or similar imaging techniques[10–13]. A higher degree of severity was found within the C6 segment. Comparison to similar studies is limited as the severity of calcifications along the course has not been investigated extensively using CBCT. Damaskos et al. [10] did, however, find a higher degree of severity in the C4 segment for their study population. One concern using the visual scale of calcification is that it leaves room for uncertainty and is open for interpretation. When using the method, all image planes should be evaluated to minimize errors. It was found that the ability to identify severe calcifications in the distal ICA had a positive predictive value for a greater than 50% stenosis[13]. Stroke can be associated with both intimal and medial dominant calcification patterns as well as the severity of the calcifications in the iICA [5]. Further studies on the clinical benefit of detecting calcifications within the ICA will be needed. However, we emphasize that all CBCT images which include the ICA taken for dental treatment should be evaluated and patients should be referred for further screening and assessment.

Multi-detector CT technology has increased the accuracy of outlining IAC calcifications[14]. The vasculature is commonly investigated with CT angiography for calcifications. Unenhanced CT was, however, recommended to better detect small amounts of calcifications[15]. The extent and distribution of the calcifications are the two main factors graded by visual inspection and this could be assessed with CBCT in our study. We advise that a thorough evaluation of the entire field of view should be done for all CBCT volumes. The lack of soft tissue information from a CBCT volume was, however, a challenge to accurately differentiate between the different iICA segments. A thorough knowledge regarding the anatomy of the head and neck is needed to identify and recognize calcifications along the course of the ICA.

5 | CONCLUSIONS

Detection of calcifications along the course of the ICA was possible using CBCT images taken for dental treatment purposes. In the studied cohort, we found a higher frequency of calcifications present within the C4, C5 and C6 segments of the ICA. The results found that the frequency of calcifications within the ICA increase with age and individuals older than 61 years of age presented with a higher number of calcifications. The prevalence of calcifications between population groups was also different, with White South African individuals showing the highest prevalence. A limitation of the study was the small sample size for the Indian population and we recommend a bigger sample size to make direct comparisons. Early detection of calcifications allows for appropriated referral and assessment which will be beneficial for patients.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

ETHICS APPROVAL
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University of Pretoria, Faculty of Health Sciences (Ethics reference number: 197/2018).

INFORMED CONSENT
Not applicable.

ORCID
André Uys https://orcid.org/0000-0001-8250-7662

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