

A retrospective review of adolescent idiopathic scoliosis in a spinal unit in Cape Town, South Africa

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Abstract

Background

The aim of this study was to retrospectively review adolescent idiopathic scoliosis (AIS) patients treated surgically at a tertiary institution in the Western Cape. Additional objectives were to determine whether clinical parameters prior to surgery are associated with specific peri- and postoperative outcomes, and to determine crude costs of AIS treatment in this spinal unit.

Methods

A retrospective observational study of clinical and radiological records was performed for 62 AIS patients treated between 1 January 2011 and 31 December 2019 at a tertiary academic hospital. Patient demographics and clinical characteristics were recorded, and appropriate correlation and associations were investigated, with post-hoc tests being performed where necessary, to investigate differences between multiple groups.

Results

The median age was 13.5 (interquartile range [IQR] 12–15) years and the cohort included predominantly females. It took a median of 405.5 (IQR 227–1 019) days before patients presented at the spinal clinic, after which they waited a median of 275 (IQR 207–379) days for surgery. The mean Cobb angle at presentation was $63.3^\circ \pm 18.5^\circ$, compared to $71.2^\circ \pm 18.3^\circ$ prior to surgery, with 18% of participants progressing from a 'non-severe curve' ($< 70^\circ$) to 'severe' ($> 70^\circ$) while awaiting surgery. A weak positive correlation was observed between the curve magnitude prior to surgery and the total theatre time, with larger curves requiring more theatre time. As expected, a significant association between the curve magnitude and the number of vertebrae levels requiring fusion ($p < 0.001$) was observed. The cost of treatment for the total study cohort amounted to more than R9 million, with a crude estimate of R89 807 per patient.

Conclusion

AIS patients treated in this study demonstrated long waiting times for surgery with a significant use of financial and physical resources. Eighteen per cent of patients progressed from a non-severe to a severe curve type due to prolonged waiting times. Early detection of AIS could potentially result in significant reduction of patients requiring surgery and as such, school and other screening programmes should be investigated as a potential tool to identify at-risk patients.

Level of evidence: 4

Keywords: scoliosis, adolescent idiopathic scoliosis, Cobb angle, spinal deformity

Introduction

Scoliosis is defined as a three-dimensional deformity of the spine with a lateral curve of more than 10° associated with axial rotation.¹ Adolescent idiopathic scoliosis (AIS) occurs in otherwise normal children between the ages of 10 and 16 years, with a global prevalence between 0.4 and 5%. Although more prevalent in females, the exact aetiology of AIS remains unknown.²

Early detection of AIS is essential for the optimum management of patients, subsequently reducing the risk of complications and downstream healthcare expenses.^{3,4} Conservative treatment, such as bracing, is widely used to minimise the risk of curve progression and thus reduce the eventual requirement for corrective surgery.^{4,5} However, to employ conservative treatment effectively, it is vital that

AIS is detected early. Several factors influence curve progression, including presenting curve magnitude, peak growth velocity, sex and age.⁶ Once AIS progresses to moderate or severe curves, patients experience more thoracic and lumbar pain, and often suffer from reduced lung capacity.^{7,8} The most important considerations for surgical intervention include failure of conservative management or having a presenting primary curve greater than $40\text{--}45^\circ$.⁹

AIS surgery is one of the most common paediatric orthopaedic procedures performed despite only 10% of all cases requiring surgery.¹⁰ Surgical management of this condition requires a multidisciplinary team including surgical, anaesthetic and nursing sub-specialties, and this intervention is mostly successful in improving quality of life and halting deformity progression.^{11,12} Takayama et al. performed a survey of quality of life (QOL) after

scoliosis surgery and reported that QOL was preserved despite a residual curve following surgery. The authors did, however, report large preoperative curves and positive sagittal balance to affect QOL negatively.¹³ Similarly, a multicentre study assessing surgical treatment of AIS using the Scoliosis Research Society Questionnaire (SRS 24) on 242 patients reported that pain improved postoperatively, and a significant improvement was observed in self-image, function and level of activity in the back domain.¹⁴ In contrast, neglected and rigid AIS with advanced curve magnitudes have an undesirable effect on patient outcomes and are associated with increased resource utilisation.^{15,16} Complications of scoliosis surgery are, however, generally low with the most disastrous being complete neurological injury accounting for 0.5–1%.¹¹

Even though surgical intervention for AIS is widely successful, the cost of scoliosis surgery is significant, with the United States reporting an annual expenditure of approximately \$514 million on AIS surgery. This is second only to appendectomies in patients aged 10–17 years.¹⁷ South Africa is one of the most urbanised and developed African countries, with more than half of the national population residing in urban areas.¹⁸ Despite this, patients still experience difficulties in accessing healthcare due to lack of awareness, lack of education, and infrastructure restraints such as lack of transport and an overburdened health system.¹⁹ In the Western Cape, there are only two specialist spinal units that provide AIS corrective surgery, with the spinal unit at our institution serving an area with a population of approximately 3.4 million people, and with trauma and infections contributing to the overwhelming majority of admissions. This trauma and infection burden subsequently utilises a significant amount of financial and theatre resources with little remaining for elective surgery.²⁰

In South Africa, to our knowledge, this is the first review of AIS in a tertiary setting focusing on, among others, demographics, curve progression, surgical management and costs. Anecdotal reports by spinal surgeons estimate that approximately 10% of patients with AIS in South Africa will present with a curve where surgery is needed. The primary aim of this study was to retrospectively review AIS patients treated surgically at a tertiary institution in the Western Cape over a nine-year period. A secondary objective was to determine whether clinical parameters prior to surgery are associated with specific peri- and postoperative outcomes. The final objective was to run a crude cost analysis to identify the expenses involved in treating these patients surgically, with specific focus on theatre time, length of hospital stay, and hardware usage.

Methods

A retrospective observational study was conducted and included AIS patients treated between 1 January 2011 and 31 December 2019 at a tertiary institution in the Western Cape province of South Africa. Ethical and institutional approval was obtained.

All patients who were diagnosed with AIS following the initial consultation were either managed conservatively or immediately routed for surgical intervention, which entailed being placed on a waiting list. Those who received corrective surgery as definitive treatment were included. This included patients initially managed nonoperatively. No specific exclusion criteria applied.

Patient records were reviewed, and patient demographic information was collected, including age at presentation, sex, and area of residence. Presenting complaint, as well as delays between symptom onset, first presentation and surgery, were also noted. The number and type of special investigations, including magnetic resonance imaging (MRI), echocardiograms and pulmonary function tests (PFTs) were recorded. All curves were measured and classified according to the Lenke system.²¹ Treatment information such as total operative time, levels fused, blood transfusion and length of hospital stay was collected.

A direct cost analysis of scoliosis surgery was performed considering theatre usage per minute, hospital stay per day and hardware use. Information was obtained via the 2018 fee schedule and the 2019 hospital implant tender document.^{22,23} Data on theatre usage was obtained from a study done in a regional public sector hospital in the Western Cape in 2020 on general operating theatre costs.²⁴

Microsoft Excel (Microsoft, Redmond, WA, USA) was used to capture the data, and STATISTICA (version 13.5, TIBCO Software) was used for analysis. Continuous data are described as means and standard deviations or medians and interquartile ranges (IQR) depending on the data distribution. Cobb angle information was dichotomised into two categories, $\leq 70^\circ$ (i.e. less severe) and $> 70^\circ$ (i.e. severe), in keeping with the categories reported by Tarrant et al.²⁵ The number of vertebra levels fused were categorised into 5–8, 9–12 and > 12 levels. Categorical variables were described as frequencies and counts. Correlations between continuous variables were investigated using Pearson's correlation coefficients or Spearman rank order correlations, depending on normality, while Pearson chi-squared analyses were performed to investigate differences between categorical variables. Post-hoc tests were performed where necessary to investigate differences between multiple groups, when overall significance was observed. Significance was accepted at the $\alpha = 0.05$ level.

Results

The study extended over a nine-year period from January 2011 to December 2019 and included 62 patients, the majority of which were female ($n = 50$, 81%), with a median age of 13.5 years (IQR: 12–15) (*Table I*). The majority of patients were located in the Cape Metropole ($n = 45$, 73%), of which 60% ($n = 27/45$) were from the Northern Tygerberg sub-district and 38% ($n = 17/45$) from the Khayelitsha Eastern sub-district. A total of nine ($n = 9$ of 62, 15%) patients initially received conservative treatment but were later treated surgically.

On initial consultation, 55% of patients ($n = 34$) complained of spinal deformity only, while 27% ($n = 17$) reported deformity and the presence of pain (*Table II*). Initial presentation to the spinal clinic took a median of 405.5 (IQR 227–1 019) days after onset of the deformity, while the median waiting time between presentation at the spinal clinic and surgical intervention was 275 (207–379) days. The median waiting time for patients who did *not* receive conservative intervention was 269 (197–351) days. While awaiting surgery, 50% ($n = 31$) of patients underwent an MRI which showed

Table I: Demographic characteristics of all patients presenting with AIS

Demographic variable	n = 62
Age (years), median (IQR)	13.5 (12–15)
Sex, n (%)	81 (50)
Female	50 (81)
Male	12 (19)
Area of residence, n (%)	
Cape Metropole	44 (71)
Northern Tygerberg	27 (44)
Khayelitsha East	17 (27)
Cape Winelands	12 (19)
West Coast	3 (5)
Overberg	1 (2)
Other	2 (3)

Data is presented as median (interquartile range) or as frequencies (counts); AIS: adolescent idiopathic scoliosis

Table II: Overview of clinical variables of all patients presenting with AIS

Clinical variable	n = 62 (%)
Presenting complaint	
Deformity	34 (55)
Pain	11 (18)
Deformity and pain	17 (27)
Special investigations	
MRI	31 (50)
Echocardiogram	5 (8)
Pulmonary function test	37 (60)
Time delay (days)	
Onset to presentation	405.5 (227–1 019)
Presentation to surgery (all)	275 (207–379)
Presentation to surgery (excluding conservative management)	269 (197–351)

Data is presented as median (interquartile range) or as frequencies (counts). AIS: adolescent idiopathic scoliosis; MRI: magnetic resonance imaging

Table III: Curve severity and surgery-specific variables

Clinical characteristic	n = 62 (%)
Lenke classification types	
Type I	33 (53)
Type II	12 (19)
Type III	6 (10)
Type IV	0 (0)
Type V	9 (15)
Type VI	2 (3)
Cobb angle (degrees)	
At presentation	63.3 ± 18.5
Prior to surgery	71.2 ± 18.3
Cobb angle category at presentation (non-severe/severe*)	46 (74.1) / 16 (25.8)
Cobb angle category at surgery (non-severe/severe*)	34 (54.8) / 28 (45.1)
Total theatre time (minutes)	448.9 ± 122.9
Number of vertebra levels fused	
5 to 8	10 (16)
9 to 12	43 (70)
> 12	9 (15)
Pedicle screws used	
8–12 screw construct	62
Additional screws used	3 (1–5)
Blood units transfused	
0–2	51 (82)
> 2	11 (18)
Hospital stay (days)	12.6 ± 6.2

Data is described as frequencies (counts), means ± standard deviation or median (interquartile range). *Non-severe < 70°, severe > 70°; data on curve severity progression excluded patients that were initially managed conservatively

no abnormalities. Echocardiograms were performed on 8% (n = 5) of patients, and 37% (n = 27) underwent PFTs. A total of 16% (n = 10) of PFTs were normal, with the most common pathology being a mild restrictive pattern in 15% (n = 9) of patients (Table II).

The most frequent curve pattern observed was a Lenke type 1 (53%, n = 33), followed by type 2 (19%, n = 12) (Table III). The mean Cobb angle at presentation was 63.3 ± 18.5°, compared to 71.2 ± 18.3° prior to surgery, with 18% of participants progressing from a 'non-severe curve' (< 70°) to 'severe' (> 70°) during the period they awaited definitive surgery. Data on curve severity progression excluded patients that were initially managed conservatively. Intraoperatively, 60 patients had a mean total theatre time of 448.9 ± 122.9 minutes. All patients had a posterior surgical approach, with the exception of one patient having an anterior approach only. The number of levels fused were categorised as 5–8, 9–12 and > 12 levels fused, with 69% (n = 43) requiring 9–12 levels fused. An 8–12 screw construct was utilised in all patients, with a median of 3 (1–5) additional screws being required. Perioperatively, 18% (n = 11) of patients received > 2 packed red cell (PRC) units and 82% (n = 51) received between 0 and 2 PRC units. The mean length of hospital stay was 12.6 ± 6.2 days (Table III).

A total of six patients (10%) experienced post-discharge complications. Two patients underwent repeat surgery for distal adding-on and another two experienced hardware failure requiring revision. Finally, two patients suffered from wound complications that required additional care.

A weak positive correlation was observed between the curve magnitude prior to surgery and the total theatre time, with larger curves requiring more theatre time (R = 0.376, R² = 0.1414, p = 0.005) (Figure 1). No association between severity of the curve and the number of blood units that were transfused was observed

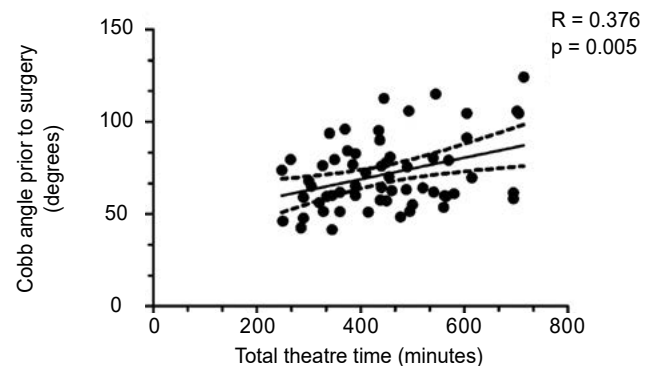


Figure 1. Correlation between Cobb angle prior to surgery and total theatre time

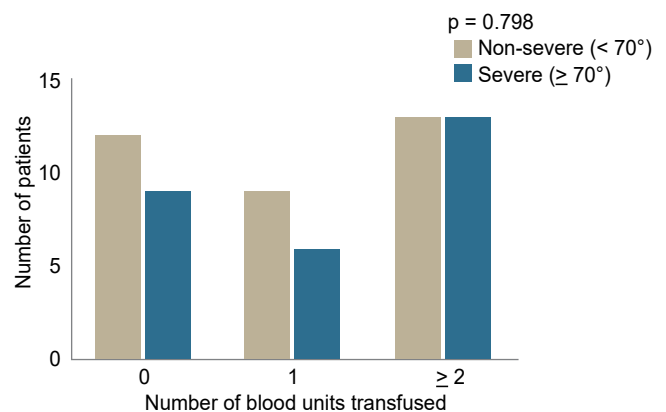


Figure 2. Investigation of the association between Cobb angle prior to surgery and number of blood units transfused

Table IV: Direct cost analysis for the treatment of AIS

Cost drivers	Cost per patient (R, n = 1)	Total cost (R, n = 62)
Theatre time (mean 448.9 minutes)*	R14 364	R890 617
Hospital stay (mean 13 days)**	R21 320	R1 321 840
Hardware:#		R3 498 826
8–12 screw construct	R43 383	R2 689 746
Additional screws used (median 3)	R10 740	R665 880
Total cost	R89 807	R9 066 909

* Theatre time cost extracted from regional public hospital research data; ** hospital stay per day cost provided by Western Cape Government hospital Uniform Patient Fee Schedule (UPFS); # hardware cost estimated from Western Cape Government tender – WCGHCC067/2019: supply and delivery of orthopaedic implants. R: ZAR, South African Rand. AIS: adolescent idiopathic scoliosis

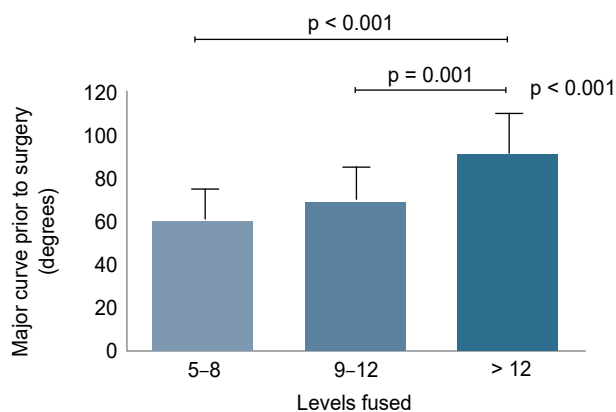


Figure 3. Association between curve magnitude and number of vertebral levels fused

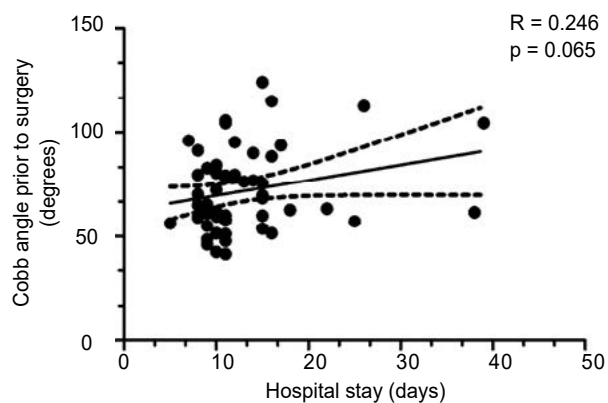


Figure 4. Association between curve magnitude and length of hospital stay

($p = 0.727$) (Figure 2). A significant association between the curve magnitude and the number of vertebral levels requiring fusion ($p < 0.001$) was observed (Figure 3). In a post-hoc analysis the differences were observed between the 5–8 and > 12 group, as well as the 9–12 and > 12 group. No relationship was observed between curve magnitude and length of hospital stay ($R = 0.246$, $R^2 = 0.061$, $p = 0.065$) (Figure 4).

Theatre cost per patient was calculated using a mean of 448.9 min/patient (Table IV) at R32/min.²⁴ A ward bed amounted to R1 640/day with a mean length of hospital stay of 13 days.²² The total hospital stay cost, for a mean length of stay of 13 days (Table III), amounted to more than R1.3 million (Table IV). Hardware costs included R43 383 for an 8–12 screw construct with rods, with the

additional requirement of a median of 3 (1–5) screws at R3 580 per screw. This amounted to more than R9 million for the total study cohort, with a crude estimate of R89 807 per patient, with a median of 3 (IQR 1–13) extra screws used.

Discussion

The current study was undertaken to review AIS cases managed surgically at a tertiary institution in a South African setting and its impact on resources. Considering the typical age of onset of AIS, screening programmes in primary and high schools are ideally placed to detect this condition early.²⁶ Internationally, school screening programmes remain a topic of considerable controversy. Japan has mandatory screening programmes, while the United Kingdom deems it unnecessary. Evidence including school screening programmes done in Africa is sparse with only Nigeria, Ghana and Rwanda having recommended that screening programmes are needed in their countries for various reasons.^{27,28} Even with the lack of studies documenting improved outcomes, low positive predictive value and over-referral, the American Academy of Orthopaedic Surgeons recommends screening girls at age 11 and 13 and boys at age 13 or 14 years.^{29,30}

All patients included in the present study were referred by either their local clinics or private general practitioners. Scoliosis school screening programmes are not included in the Integrated School Health Policy by the Department of Health in South Africa,³¹ and as such, no patients in the present study were identified through school screening programmes. A previous investigation done in the Johannesburg Metropole in 2005 considered the burden of scoliosis in 32 primary schools. By screening 320 children in the independent schools and 374 children in the government schools, the incidence of scoliosis was 8% overall and higher than the United States with an incidence of 2–3%.^{32,33} Various studies have highlighted the inequities in access to healthcare in South Africa and report that inaccessibility to healthcare facilities remains a barrier, especially in remote, poorly resourced rural areas.^{18,19} Screening programmes designed to detect major healthcare concerns early are therefore especially beneficial in communities that might not otherwise have easy access to healthcare services.

Our institution serves a population of nearly 3.5 million people. Communities situated in this district experience low socioeconomic circumstances and low employment rates.³⁴ This potentially explains the delayed presentation reported in our study group. Our cohort consisted mainly of young female patients, commonly presenting with a spinal deformity, of which a third complained of associated pain. A previous review article reported that the presence of back pain is not associated with the size of the deformity, but rather the specific curve type. The authors noted that, similar to our study, 53% of the patients had spinal deformities classified as Lenke I. They further reported that 42% of their cohort complained of back pain.³²

In the present study, 49 patients at first presentation had a curve that already met the surgical threshold of $> 50^\circ$, even though they were still classified as being ‘non-severe’ according to the categories reported by Tarrant et al.²⁵ However, these patients still had to wait a median of 275 days before finally undergoing surgery. Consensus through the Canadian Paediatric Surgical Wait Times Project concluded that a waiting time of six months or more resulted in increased curve progression, longer theatre time, more levels fused and other adverse events.^{10,25} Curve progression in the present study was therefore a major concern, with a mean Cobb angle increase of 9° degrees during the waiting time until surgery, which resulted in 18% of patients progressing from a ‘non-severe’ ($\leq 70^\circ$) to ‘severe’ ($> 70^\circ$) curve type. It is very likely that the prolonged waiting time for surgery was directly responsible for this observed curve severity progression. Furthermore, even

though we failed to show it convincingly in the present study due to the relatively small sample size, it is not unreasonable to argue that increased curve severity could lead to increased theatre time and the requirement of more spinal vertebra levels needing to be fused. This not only has a more significant effect on the patient, but also results in increased resource use, especially in a resource-constrained setting. Fortunately, no serious direct complications were observed in patients with documented curve progression in the present study. This study did not, however, gauge QOL or any psychological measures.

Preoperative curve magnitude did not influence the need for blood transfusions, major postoperative complications, or length of hospital stay, which is highly reassuring for both patients and surgeons. In 2012, Miyanji et al. similarly reported no association between hospital length of stay and curve magnitude.¹⁵ However, the present study has a relatively small sample size and thus is not powered to detect large differences – as such, these findings should be interpreted with caution. As expected, an association with curve magnitude and the number of vertebrae fused was observed. This finding is supported in the literature with authors noting increased operative times and fusion levels with more severe curve magnitudes.^{15,16} Future longitudinal studies investigating the long-term outcomes and QOL of patients that underwent AIS surgery should be conducted. It is widely known that complication rates in adults are much higher than in children, and when surgery is performed closer to adulthood, the risk of infection and pseudoarthrosis is almost 17%.³³ Scoliosis surgery should be done as early as possible to avoid additional surgery and risk of adverse events as per the guidelines of the Canadian Paediatric Surgical Wait Times Project.¹⁰

Besides the impact surgical intervention for AIS has on the patient, AIS corrective surgery also utilised a significant amount of financial resources. With a mean theatre time of 7.5 hours and a crude mean cost of ~R90 000 per patient, the time and financial implications of treating each individual patient are substantial. The spinal unit at our institution has a single theatre slot per week (eight hours) dedicated to elective surgery, which includes other elective surgeries besides AIS. Deformity correction surgeries are often lengthy procedures. At this institution, Miseur et al. reported a deformity elective case to take just over seven hours.²⁰ This effectively reduces the number of patients that can be treated each week. In addition, the unit lacks a static paediatric spinal theatre team. It has been shown that a static team approach, consisting of the surgeon, anaesthesiologist, physiologist and nursing staff team who are all familiar with the type of surgery makes a positive impact on the quality, efficacy and safety of surgical patients.¹² A recent study did a comparative analysis between specialist Paediatric Spinal Surgical Teams (PSST) and various outcomes, including surgical site infection, operating theatre time, blood loss and length of hospital stay. A significant reduction was observed in all outcomes after implementation of a PSST.^{35,36} It is therefore tempting to speculate that a well-versed team, familiar with each other and the surgical procedure, might have a positive influence on the patients and healthcare system.

The most important limitation of this study was the relatively small sample size, even though the study was conducted over a nine-year study period. Future multicentre studies might alleviate some of the limitations associated with small sample sizes. Finally, financial implications of the treatment of AIS between 2011 and 2019 might have differed substantially, especially given that the 2018 and 2019 fee structures were used to estimate cost. However, the type of treatment that patients were provided in the early study years remains comparable to the later study years, and therefore the estimated cost could be argued to still be relevant.

Future research should aim to include multiple study sites and investigate whether the use of static theatre teams could potentially improve service delivery and financial burdens in the treatment of AIS. In addition, longitudinal investigation of patients who underwent AIS corrective surgery would provide more insight into the long-term outcomes of these patients and whether they re-presented at a later stage, in adulthood, for further treatment.

Conclusion

AIS patients treated in this study demonstrated long waiting times for surgery with a significant use of financial and physical resources. Eighteen per cent of patients progressed from a non-severe to a severe curve type due to prolonged waiting times. Early detection of AIS could potentially result in significant reduction of patients requiring surgery and as such, school and other screening programmes should be investigated as a potential tool to identify at-risk patients.

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: Health Research Ethics Committee, University of Stellenbosch, Project ID 1448, and ethics reference number S20/02/028.

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.

A waiver of informed consent was obtained for this 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

NLA: study conceptualisation, data capture, first draft preparation, manuscript preparation, approval of final manuscript

MCB: study design; data analysis, manuscript preparation, approval of final manuscript

SM: study conceptualisation, data capture, manuscript preparation, manuscript revision, approval of final manuscript

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