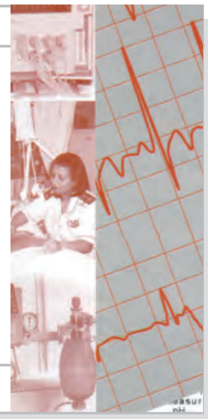
ARTICLE

The effect of penetrating trunk trauma and mechanical ventilation on the recovery of adult survivors after hospital discharge



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Objectives. To establish whether survivors of penetrating trunk trauma recover adequately and spontaneously following critical illness.

Material and methods. A prospective observational study was conducted. Intubated and ventilated males and females with penetrating trunk trauma (SV group (mechanical ventilation (MV) <5 days, *N*=13), LV group (MV ≥5 days, *N*=29)) were recruited from four intensive care units. Dynamometry, lung function tests, 6-minute walk distance (6MWD), oxygen uptake and quality of life (QOL), assessed with the short form-36 English UK version (SF-36) questionnaire, were recorded over a 6-month period following discharge. Results were compared with a healthy control group (*N*=40).

Results. In the LV group, 6MWD was reduced in comparison wit h controls at 1 (p=0.00) and 3 months (p=0.00) after discharge. Morbidity correlated with 6MWD at 3 (p=0.03) and 6 months (p=0.02), and there was a reduction in strength at 1, 3 and 6 months relative to the SV group and controls (p=0.00 - 0.04). In addition, intensive care unit and hospital length of stay correlated with muscle strength at 1 and 3 months for these subjects. SF-36 physical health domains were significantly reduced for LV group subjects up to 6 months compared with the SV group and controls (p=0.00 - 0.02).

Conclusion. SV group subjects recovered adequately and spontaneously within 3 months of discharge. LV group subjects, however, had significant limitations in exercise capacity, muscle strength and physical components of QOL up to 6 months after discharge. Persistent impairment of function is related to duration of illness and immobility.

South Africa has a high incidence of violence and death due to unnatural causes. Sixty thousand unnatural deaths occurred in South Africa in 2004, and violence accounted for 39% of these.[1] Homicide is one of the major causes of death for South African men,[2] with a reported incidence of firearm-related homicide of 63/100 000.[3] Consequently, gunshot and/or stab wounds to the trunk are commonly encountered injuries in South African hospitals. Penetrating trauma accounts for almost 60% of all trauma cases in South Africa,[4] and common underlying factors contributing to these injuries are alcohol and drug abuse.[2]

Penetrating trauma frequently necessitates explorative surgical intervention to identify and treat injuries to the internal organs. During this period patients are managed in the intensive care unit (ICU) and require prolonged mechanical ventilation (MV) and bed rest. Along with increased muscular catabolism due to sepsis and the use of drugs such as corticosteroids, neuromuscular paralysing agents and aminoglycosides, this contributes to muscle dysfunction.[5,6] The 2002 Brussels Roundtable Discussions among intensive care practitioners concluded that survivors of intensive care suffered from poor functional capabilities and decreased quality of life (QOL) and frequently did not return to work, all of which places an increased burden and considerable stress on families and informal caregivers.[7]

The researchers are unaware of any database that describes the rate of recovery, specifically pulmonary function, muscle strength, exercise capacity and QOL, of adult survivors of penetrating trunk trauma. Rehabilitation programmes for patients with chronic cardiac and/or pulmonary diseases do exist in South Africa, and have been shown to be effective in improving functional capacity of these patients with regard to work and activities of daily living. However, without knowledge of the degree and rate of recovery of trauma survivors, it is uncertain whether they too would benefit from such a programme after discharge.

The purpose of this study was to document the recovery rate over the 6-month period after hospital discharge, with reference to exercise capacity, muscle strength, pulmonary function and QOL, of adult survivors of penetrating trunk trauma requiring MV.

Materials and methods

Patient characteristics

A longitudinal observational prospective study was performed on a cohort of adult patients who survived penetrating trunk trauma. Patients were recruited from four major trauma centres in the Johannesburg area. They were divided into two groups according to duration of mechanical ventilation in the ICU: the SV group consisted of those who were ventilated for <5 days and the LV group of those ventilated for ≥5 days. According to Stricker and colleagues there is no generally accepted definition of a prolonged ICU stay, as this has variously been reported as ranging from 4 to 30 days.[8]

Male or female patients aged between 18 and 60 years who had been admitted to an ICU and intubated and mechanically ventilated in the course of treatment of penetrating trunk trauma (abdomen and/or chest) were considered to be eligible for inclusion. Patients were also required to be independently mobile or mobile with minimal assistance at hospital discharge.

Admissions to the ICUs of the four recruitment hospitals were monitored on a weekly basis. The severity of illness of each potential subject was established within the first 24 hours of admission by means of the Acute Physiology and Chronic Health Evaluation (APACHE II) scoring system, and morbidity was established using the Sequential Organ Failure Assessment (SOFA) score. The SOFA score was calculated daily for the first 7 days and thereafter twice weekly for the duration of ICU stay. Subjects who consented to participate in the study were evaluated at 1, 3 and 6 months following discharge from the hospital. Each subject completed a demographic questionnaire and at each visit underwent: (*i*) a pulmonary function test; (*ii*) an oxygen uptake treadmill test; (*iii*) a muscle strength test with a hand-held dynamometer; (*iv*) a standardised 6-minute walk distance test (6MWD); and (*v*) a QOL assessment with the short form-36 English UK version (SF-36) questionnaire.

Dynamometry protocol

Dynamometry measurements of the left and right deltoid, biceps, triceps, quadriceps and hamstring muscles of each subject were made with a hand-held dynamometer (MicroFet2, Hoggan Health Industries). Test procedures were described in a previous publication.[9] Three measurements were recorded for each muscle group and the mean strength was calculated.

Six-minute walk distance test protocol

A standardised protocol, described in the American Thoracic Society Statement,[10] was used to administer this test over a 30-metre distance. The test procedure was described in a previous publication.[9]

Oxygen uptake protocol

A treadmill walk protocol for unfit subjects, as described by Naughton and colleagues,[11] was used. This is an intermittent-incremental protocol. Distance walked was measured through the distance meter on the treadmill. Subjects walked to the point of exhaustion, at which time the test was terminated. Test procedure was described in a previous publication.[9]

Pulmonary function test protocol

Pulmonary function was assessed using the Jaeger System. The following tests were recorded: total lung capacity (TLC), forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), FEV_1/FVC, residual volume (RV) and gas transfer (DLCO). These tests were performed according to American Thoracic Society criteria[12] by qualified lung function technologists and predicted values were according to the European Community for Coal and Steel new version with a 10% correction made for non-Caucasian subjects.[13]

Quality of life assessment

Subjects completed the SF-36 questionnaire. The questionnaire was self-administered and help was only provided to the subject if he/she did not understand what was being asked. No attempt was made to influence the subject's responses to the questions asked in the questionnaire. On average subjects took 10 - 15 minutes to complete the questionnaire.

Control group

Forty volunteers, resident in Johannesburg and Pretoria and of similar age, gender and pre-admission activity level to the study subjects, were recruited. None reported any chronic disease conditions. A cross-sectional study design was used to collect data from these volunteers for exercise capacity, muscle strength and QOL as described above.

Ethical considerations

Permission to conduct the study was obtained from the University of the Witwatersrand Committee for Research on Human Subjects (Medical). Consent was obtained from the hospital and ICU directors of the relevant hospitals. Written consent was obtained from all subjects who participated. Confidentiality was maintained by coding all data that were collected and captured.

Data analysis

Demographic information was summarised using means and standard deviations (SDs) as well as frequencies, percentages and cross-tables. A one-way analysis of variance (ANOVA) and ANOVA for ranks test was performed on the above parameters. Groups were compared with respect to the categorical parameters using the chi-square test and Fisher's exact test. Quantitative information was expressed as means and SDs. For changes in these outcome measures over time, the SV and LV groups were compared using a repeated-measures ANOVA. At 1, 3 and 6 months, results for the SV and LV groups and the control group were assessed using a one-way ANOVA. In pair-wise comparisons of these groups Bonferroni corrections were made. Spearman correlations were calculated between the APACHE II and maximal SOFA scores with the peak oxygen uptake (VO_{2peak}) VO_{2peak} distance and 6MWD distance. Spearman correlations (using the APACHE II, SOFA, ICU and hospital LOS) were made with muscle strength scores at 1, 3 and 6 months. With respect to SF-36 data, groups were compared, i.e. the SV group with the LV group and the SV and LV groups with the control group, using the independent *t*-test for unequal variance. The STATA 8 statistical software package was used for all statistical analyses, and testing was done throughout at the 0.05 level of significance.

Results

Demographic characteristics

A total of 203 patients with penetrating trunk trauma were admitted during the data collection period. Forty-two patients gave consent and were included in the study. The demographic characteristics of the participants are outlined in Table I. Subjects were excluded due to the following: death in the ICU (*N*=42), declined participation (*N*=38), spinal cord or head injury (*N*=25), no contact details after hospital discharge (*N*=10), police custody after discharge (*N*=16), residence outside Johannesburg and surrounding area (*N*=7), complex lower limb fractures (*N*=6), unilateral upper limb paralysis (*N*=7), unilateral lower limb paralysis (*N*=5), recurrent pleural effusions (*N*=1), chronic obstructive pulmonary disease (*N*=1), epilepsy (*N*=1), loss of eyesight due to gunshot wound (*N*=1), and history of recurrent myocardial infarction (*N*=1).

The SOFA score and length of stay (LOS) in the ICU and hospital were significantly greater in the LV subjects. Thirty-two subjects were from the lower socio-economic level (monthly income ≤R1 000) and may have been exposed to crime and violence on a regular basis. All subjects received in-hospital physiotherapy, but none received physiotherapy after discharge. No deaths were reported from discharge to 6 months. No statistically significant difference was detected between the groups with regard to resumption of work over the 6-month period. At 6 months, 4 subjects in the SV group had returned to their pre-admission level of exercise/sport. Ten LV subjects had returned to exercise/sport at 6 months, but not at the level reported before injury. Two subjects in the SV group and 7 in the LV group still reported a sedentary lifestyle at the 6-month assessment.

Control group

There were no hospitalisations during the 12 months prior to recruitment. The mean age of this group was 29.5 (SD 8.5) years and the mean body mass index (BMI, kg/m^2) 24.9 (SD 4). Thirty-nine were male and 1 female. There were no statistically significant differences in age (p=0.074), gender (p=0.561) or BMI (p=0.494) between the control group and the other two groups.

Pulmonary function test

All the pulmonary function outcome measures were within the normal range for both the SV and LV groups, with no statistically significant differences between the groups.

Oxygen uptake test

There was no statistically significant difference between the SV and LV groups' performance. The mean

Table I.	Demographic characteristics of 42 survivors of penetrating trunk trauma		
Variable	**SV group (*N*=13)**	**LV group (*N*=29)**	***p*-value**
Age (yrs) (mean (SD))	28.3 (8.9)	33.6 (8.2)	NS
Gender	12 male 1 female	28 male 1 female	NS
APACHE II (mean (SD))	20.2 (4.7)	18.7 (4.3)	NS
BMI (kg/m^2) (mean (SD))			
1 mo.	22.7 (5.0)	24.2 (5.9)	NS
6 mo.	23.5 (5.5)	26.4 (6.9)	NS
Maximal SOFA (mean (SD))	9.7 (2.9)	11.7 (2.8)	0.038
Length of MV (d) (mean (SD))	2.3 (1.1)	19.5 (13.4)	0.000
ICU LOS (d) (mean (SD))	6.8 (5.6)	26.6 (18.1)	0.000
Hospital LOS (d) (mean (SD))	23.8 (18.4)	42.3 (30.8)	0.013
Gunshot-related injury	62% (*N*=8)	90% (*N*=26)	N/A
Inotropic support in ICU	15.4% (*N*=2)	34.5% (*N*=10)	N/A
Staged reconstruction of abdominal wall at 6 mo.	7.7% (*N*=1)	20.7% (*N*=6)	N/A

SV group = mechanical ventilation <5 days; LV group = mechanical ventilation ≥5 days; MV = mechanical ventilation; NS = not significant; N/A = not applicable; BMI = body mass index; APACHE II = Acute Physiology and Chronic Health Evaluation; SOFA = Sequential Organ Failure Assessment; LOS = length of stay.

distance walked on the treadmill improved by 517.8 m for the SV subjects and by 321.6 m for the LV subjects over the 6-month period. Observed VO_{2peak} improved by 7.8 ml/kg/min for the SV subjects and 4 ml/kg/min for the LV subjects.

Six-minute walk distance test

The resting heart rate (HR) in the SV and LV subjects was significantly higher (p=0.02 and p=0.00, respectively) at 1 month and for LV subjects at 3 months (p=0.04) when compared with the controls. HR measured immediately after exercise was significantly lower in the LV group at 1 (p=0.00) and 3 months (p=0.03) compared with controls. Fig. 1 displays the distance walked during the 6MWD.

The controls walked significantly further than the subjects in the LV group at 1 (p=0.00) and 3 months (p=0.00). No statistically significant differences were observed between these groups at 6 months. The SOFA score had a statistically significant correlation with distance walked during the 6MWD at 3 (p=0.03) and 6 (p=0.02) months for the LV subjects.

Dynamometry results

The SV subjects had significantly greater strength in most muscle groups (p=0.002 - 0.04) at 1 month in comparison with the LV group, and significant differences in biceps, triceps, quadriceps and hamstring muscle strength were still present at 6 months (Figs 2 and 3).

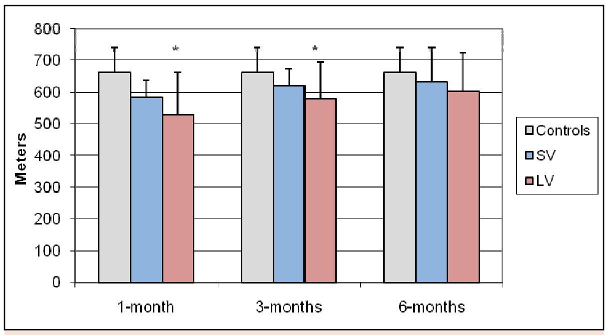

*Fig. 1. Distance walked on 6MWD (data expressed as means) (*p<0.05; SV = mechanical ventilation <5 days; LV = mechanical ventilation ≥5 days).*

The SV subjects had significantly weaker right deltoid and right triceps (p=0.00, respectively) muscle strength at 1 month in comparison with the controls. This muscle weakness had, however, resolved at 3 months. In contrast, the LV subjects had persistent weakness of all upper limb muscle groups from 1 (p=0.00) to 6 months (p=0.00) when compared with the controls (Fig. 2).

SV subjects had significant weakness of both quadriceps (p=0.00) and right hamstring (p=0.03) muscles 1 month after discharge. This weakness had resolved by 3 months. The LV subjects had significant

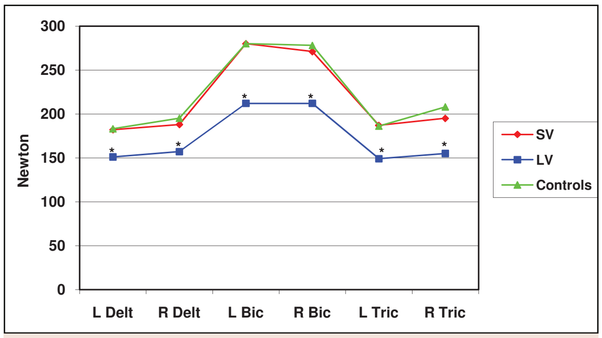

*Fig. 2. Dynamometry results for upper limbs at 6 months after discharge (data expressed as means) (L = left; R = right; Delt = deltoid muscle; Bic = biceps muscle; Tric = triceps muscle; *p<0.05; SV = mechanical ventilation <5 days; LV = mechanical ventilation ≥5 days).*

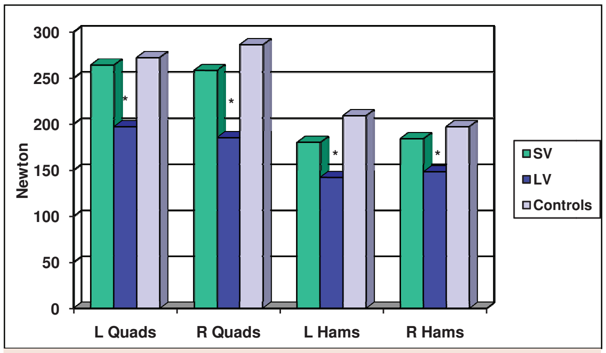

*Fig. 3. Dynamometry results for lower limbs at 6 months after discharge (data expressed as means) (L = left; R = right; Quads = quadriceps muscle; Hams = hamstring muscle; *p<0.05; SV = mechanical ventilation <5 days; LV = mechanical ventilation ≥5 days).*

weakness of both quadriceps (p=0.00) and hamstrings (p=0.00) from 1 to 6 months when compared with the controls. No statistically significant relationships were found between APACHE II and SOFA scores and muscle strength at any of the three assessments for any subjects. No statistically significant relationship between ICU LOS and muscle strength and hospital LOS and muscle strength was noted for the SV subjects at any assessments. However, a strong relationship was found between ICU LOS and right deltoid (r=-0.513; p=0.012), right triceps (r=-0.473; p=0.022) and right hamstring (r=-0.549; p=0.006) strength at 1 month and left triceps (r=-0.445; p=0.049) strength at 3 months for the LV subjects. A similarly strong association was found between hospital LOS and left deltoid (r=-0.553; p=0.006), right triceps (r=-0.613; p=0.001), left hamstring (r=-0.587; p=0.003) and right hamstring (r=-0.753; p=0.000) strength at 1 month and between left deltoid (r=-0.569; p=0.008), left triceps (r=-0.589; p=0.006), right triceps (r=-0.556; p=0.01) and right hamstring (r=-0.452; p=0.045) strength at 3 months for LV subjects.

Quality of life

No statistically significant difference was found for the domain or summary scores between the SV and LV groups 1 month after hospital discharge. There was a statistically significant difference between the groups for the physical function (p=0.004), bodily pain (p=0.003) and general health (p=0.02) domains and the physical component summary score (p=0.004) but not for the mental component summary score (p=0.616) at 6 months. QOL related to physical health (PCS) was significantly different between the SV subjects and the control group at 1 and 3 months (Table II). PCS was significantly different between the LV subjects and controls from 1 to 6 months (Table III).

Discussion

An important finding of this study was that subjects who received a short period of MV recovered adequately on their own by the third month after discharge with regard to exercise capacity, muscle strength and QOL. Subjects who received prolonged MV showed some improvement in exercise capacity, muscle strength and QOL, but were still significantly weaker than SV subjects and controls 6 months after discharge. LV subjects had a significantly higher morbidity than SV subjects, with a significantly higher incidence of sepsis and organ failure. The systemic inflammatory response syndrome, triggered by trauma and blood loss, leads to the release of pro-inflammatory cytokines (interleukin-1, interleukin-6, tumour necrosis factor alpha (TNF-α)).[6] TNF-α is responsible for the production of reactive oxidant species (ROS) and nitric oxide (NO) from polymorphonuclear leucocytes, monocytes and the vascular endothelium. NO further contributes to muscle protein breakdown through the ubiquitin-proteasome pathway.[6,14] All contribute to muscle protein breakdown and weakness. None of the LV subjects received neuromuscular blocking agents during their ICU stay and none had difficulty weaning from MV. The muscle weakness observed is therefore more likely to be caused by significant muscle catabolism due to inflammation from sepsis or trauma than by critical illness polyneuropathy.[15] We did not perform electromyography, so this cannot be confirmed. Although the activity of inflammatory cytokines ceases after initial source control and after any sepsis and organ failure has resolved, recovery from the effect of muscle protein breakdown seems to be prolonged and incomplete for LV subjects, even at 6 months after discharge.

In this study exercise capacity in SV subjects seemed to improve at a faster pace over the 6 months after discharge than that in LV subjects. This improvement occurred without any improvement in pulmonary function, and so probably represented an increase in cardiac or skeletal muscle function and/or oxygen extraction ratio. Another factor favouring the more rapid improvement in exercise capacity in SV subjects was their shorter ICU stay and lower morbidity. This is in contrast to the LV subjects, in whom the higher morbidity was associated with prolonged ICU and hospital stay and contributed to muscle atrophy and

Table II. SF-36 composite score comparisons between SV and control groups

Composite scores	Mean SF-36 composite score values								
	1 month			3 months			6 months		
	SV (*N*=7)	Control (*N*=40)	*p*-value	SV (*N*=7)	Control (*N*=40)	*p*-value	SV (*N*=6)	Control (*N*=40)	*p*-value
PCS	42.8 (3.9)	57.6 (5.1)	0.000*	51.2 (9.0)	57.6 (5.1)	0.011*	57.2 (5.5)	57.6 (5.1)	0.855
MCS	44.9 (10.5)	50.3 (10.3)	0.212	53.3 (3.9)	50.3 (10.3)	0.464	51.8 (6.1)	50.3 (10.3)	0.725

Data expressed as norm-based mean (SD).
*$p<0.05$.
SV = mechanical ventilation <5 days; PCS = physical health composite score; MCS = mental health composite score.

Table III. SF-36 composite score comparisons between LV and control groups

Composite scores	Mean SF-36 composite score values								
	1 month			3 months			6 months		
	LV (*N*=23)	Control (*N*=40)	*p*-value	LV (*N*=20)	Control (*N*=40)	*p*-value	LV (*N*=17)	Control (*N*=40)	*p*-value
PCS	38.5 (5.1)	57.6 (5.1)	0.000*	40.8 (8.3)	57.6 (5.1)	0.000*	45.4 (8.4)	57.6 (5.1)	0.000*
MCS	47.9 (10.8)	50.3 (10.3)	0.383	50.6 (7.8)	50.3 (10.3)	0.915	53.8 (8.4)	50.3 (10.3)	0.23

Data expressed as norm-based mean (SD).
*$p<0.05$.
LV = mechanical ventilation ≥5 days; PCS = physical health composite score; MCS = mental health composite score.

weakness. In fact, in-hospital morbidity did correlate significantly with 6MWD at 3 and 6 months. Few studies have investigated the effects of critical illness on recovery of exercise capacity in the first 6 months following discharge.[16] Herridge and colleagues reported a median 6MWD of 281 m and 396 m for ARDS survivors at 3 and 6 months respectively, and restrictive pulmonary complications in 6% of subjects.[16] The SV subjects in our study performed better than the above with median walk distances of 633 m and 680 m respectively, as did the LV subjects with median walk distances of 586.5 m and 626 m respectively. The SV and LV subjects performed better due to the fact that no pulmonary dysfunction was observed on pulmonary function tests over the 6-month study period.

The SV and LV subjects generally demonstrated fast recovery in the mental health components (MCS) of QOL. Cuthbertson *et al.*[17] reported similar findings in a mixed ICU population, attributing this to a 'mental high' in their subjects 'as they had cheated death'. It is probable that this 'mental high' was present in the subjects in our study, almost all of whom commented that they were glad to be alive after their ordeal. LV subjects had significant reductions in the physical components of QOL compared with their counterparts 6 months after discharge. Granja *et al.*[18] and Herridge *et al.*[16] reported similar reductions in physical components of QOL in survivors of sepsis 6 months after discharge.

A limitation of this study was the problem in distinguishing between patients with penetrating chest trauma and those with penetrating abdominal trauma, due to the small number of subjects. The high dropout rate observed in SV subjects (46%) is a concern, as the small number of subjects might have led to a type II error. Results obtained for this group of subjects at the three assessments should therefore be interpreted with caution. The researchers speculate that these subjects felt sufficiently well from a mental and physical point of view not to deem follow-up appointments necessary. High dropout rates in trauma patients are well recognised, however,[17,19] and were expected during this study.

Conclusion

This study on the recovery of survivors of penetrating trunk trauma who received MV was the first of its kind to be conducted in South Africa. This was also one of a few studies, on an international level, that objectively assessed the recovery of exercise capacity and muscle strength in survivors of critical illness. Subjects who received prolonged MV suffered from prolonged muscle weakness, exercise limitations and reduced QOL related to physical function up to 6 months following discharge due to their severity of illness. On the basis of the results of this study, it is recommended that for these subjects rehabilitation after hospital discharge be implemented to enhance their recovery.

The authors would like to thank Mr Christo van der Westhuizen and Mr Arrie Oberholster, Pulmonary Function Unit, Pulmonology Department, Charlotte Maxeke Johannesburg Academic Hospital for conducting the pulmonary function tests for this study, as well as Mr Zac van Heerden, Centre for Exercise Science and Sport Medicine, Wits Education Campus, Johannesburg, for conducting the oxygen uptake tests.

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Any opinions, findings and conclusions or recommendations expressed in this article are those of the authors, and therefore the NRF does not accept any liability with regard thereto.

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