EFFECT OF THE COVID-19 NATIONAL LOCKDOWN ON ROAD TRAFFIC ACCIDENT FATALITIES INVOLVING TRAUMATIC BRAIN INJURY: A RETROSPECTIVE REVIEW OF SALT RIVER MORTUARY CASES

by

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Declaration

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Abstract

Background: Low- and middle-income countries have reported higher traumatic brain injury (TBI) incidence and mortality rates in cases involving road traffic collisions (RTCs). In South Africa, RTCs are commonly reported as contributors to death; however, the current burden of TBI attributable to these deaths is unknown. Additionally, movement restrictions and behavioural changes introduced during the COVID-19 nationwide lockdown have been shown to affect injury patterns in general, but their impact on TBI is undocumented. This study aimed to investigate the epidemiology and patterns of TBI-associated deaths attributable to RTCs before and during the nationwide lockdown in South Africa.

Methods: Autopsy reports of TBI-associated deaths due to RTCs, reported to Salt River Mortuary between 1 January 2019 and 31 December 2020, were reviewed.

Results: A total of 616 RTCs, from the 7694 total caseload, were included with RTC-related TBIs accounting for 6.51% of the caseload across two years. Males were three times more likely to present with RTC-related TBIs compared to females. Individuals aged 30-39 years were at the highest risk of RTCs, and the median age of those with TBI (34 years) was significantly younger than those without (39 years, $p < 0.001$). Furthermore, the proportions of the TBI cases were comparable across all road user groups, all were equally likely to sustain TBI in an RTC. Two-thirds (66.18%) of individuals died before hospital admission. Of the 47.16% deceased individuals whose alcohol concentration was detectable, 92.96% had an alcohol level of ≥ 0.05 g/100 mL however we found no significant association between alcohol consumption and sustaining a TBI.

Conclusion: These findings indicated that younger individuals are at a higher risk of TBI in RTC-related deaths. Furthermore, injury patterns did not seem to differ between the periods before compared to during the COVID-19 lockdown.

Keywords: Traumatic Brain Injury, Road Traffic Collision, COVID-19 National Lockdown

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Abbreviations

AIS	Abbreviated Injury Scale
BAC	Blood alcohol concentration
CDC	Centers for Disease Control and Prevention
COVID-19	Coronavirus disease 2019
CT	Computed tomography
DAI	Diffuse axonal injury
DFMT	Division of Forensic Medicine and Toxicology
EDH	Epidural haemorrhage
FPOs	Forensic Pathology Officers
FPS	Forensic Pathology Services
GCS	Glasgow Coma Scale
HICs	High-income countries
HREC	Human Research Ethics Committee
ICH	Intracranial haemorrhage
ICU	Intensive care unit
IVH	Intraventricular haemorrhage
LMICs	Low-and middle-income countries
LOC	Loss of consciousness
MRI	Magnetic resonance imaging
PTA	Duration of post-traumatic amnesia
RICP	Raised intracranial pressure
RTC	Road Traffic Collision
SRM/OFPI	Salt River Mortuary/Observatory Forensic Pathology Institute

SA	South Africa
SAH	Subarachnoid haemorrhage
SDH	Subdural haemorrhage
SSA	Sub-Saharan Africa
TBI	Traumatic Brain Injury
UCT	University of Cape Town
USA	United States of America
WHO	World Health Organisation

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Chapter 1: Literature Review

1.1. Introduction

Traumatic brain injury (TBI) is a leading cause of morbidity and mortality around the world (Dinsmore, 2013). According to Abio et al. (2021), out of the 7.3 billion people worldwide, between 0.37% and 1% (27.0–69.0 million people) are diagnosed with TBI each year, with an incidence of between 0.35% and 1% (351–939 cases per 100,000 population) and a mortality rate of 0.0095% (9.5 per 100,000 population) (Abio et al., 2021). TBI is caused by a bump, blow, or jolt to the head or a penetrating head injury that ultimately results in the disruption of normal brain function and/or structure (Centers for Disease Control and Prevention [CDC], 2022). This may result in a myriad of signs and symptoms such as a decreased state of consciousness, amnesia, various neurological and cognitive disorders, skull fractures, intracranial lesions or even death (Kalyan, Nadasan & Puckree, 2007).

Due to the invisible nature and heterogeneity of certain TBI symptoms, such as impairments in memory and cognition, most mild cases usually go unreported and this has led to TBI being dubbed a 'silent epidemic' (Iaccarino et al., 2018). Additionally, the heterogeneity of the clinical signs and presentation following TBI makes it challenging to diagnose in certain cases, further leading to possible misdiagnosis and underestimation of its true burden (Tenovuo et al., 2021). Furthermore, in severe cases, individuals with TBI may die instantly and be transported directly to the mortuary or survive a few minutes after the traumatic incident and die during transportation to emergency units. These two groups would lead to the underestimation of such deaths, particularly in hospital surveillance systems (Tran et al., 2015; Eaton et al., 2017).

Low-and-middle-income countries (LMICs) such as sub-Saharan (SSA) countries, have shown severe TBI outcomes in comparison to high-income countries (HICs) such as the United States of America (USA). This could be due to the lack or limited access to appropriate and timeous emergency and neurosurgical intervention in some of these LMIC regions (Negida et al., 2021). Higher TBI mortalities can be directly linked to unfavourable TBI outcomes in the presence of high levels of violence. This leads to overburdened mortuaries, underscoring the need for appropriate surveillance systems which must include mortuary data to record and mitigate these fatalities.

In South Africa (SA) for example, the high burden of violent injury and mortality has been previously described (Norman, 2007) but the current burden of TBI from these injuries remains unknown. This makes it difficult to understand the epidemiology of TBI, trends over time and associated risk factors. An older study performed more than three decades ago reported an incidence of 316 TBI injuries per 100,000 individuals, with interpersonal violence being the leading cause of the injuries (Nell & Brown, 1991). Similarly, the current burden of TBI at the Salt River Mortuary/Observatory Forensic Pathology Institute (SRM/OFPI) in Cape Town is also unknown, with the previous epidemiological study being far outdated (Austen et al., 1987). Considering this scarcity of TBI data, the purpose of this literature review was to investigate and compare the incidence and mortality rates of TBI across HICs compared to LMICs. In addition, we aimed to review the risk factors responsible for the reported patterns of TBI.

1.2. TBI aetiology

The accurate diagnosis of TBI requires access to clinical expertise, neurocognitive testing, and radiological imaging. Brain injuries can be classified as focal or diffuse (Kalyan, Nadasan & Puckree, 2007). Focal lesions such as contusions and lacerations are localised to the area of impact, whilst diffuse lesions affect wider regions of the brain and include diffuse axonal injury. These injuries may occur either as a primary or secondary brain injury (Kalyan, Nadasan & Puckree, 2007; Dinsmore, 2013). Primary injuries are sustained immediately after an impact, and include injuries to the neural and vascular elements of the brain, whilst secondary injuries occur as a result of delayed (minutes, days or months later) physiological effects that result in further damage to the brain tissue (Kalyan, Nadasan & Puckree, 2007; Dinsmore, 2013; Galgano et al., 2017).

Several cognitive and other medical tests can be performed to diagnose and evaluate the severity of TBI in pre-hospital settings and emergency rooms. Some of these include the Glasgow Coma Scale (GCS), the Abbreviated Injury Scale (AIS), the duration of post-traumatic amnesia (PTA) and the duration of loss of consciousness (LOC) (Van Deynse et al., 2022). The GCS is the most frequently employed test to assess TBI severity (Faul & Coronado, 2015). This score—which includes the motor, verbal, and eye movement scores—is routinely applied depending on the treating health practitioner, hospital facility, patient symptoms and, medical interventions such as sedation. Using this score, TBI can either be classified as mild (GCS between 15 and 13), moderate (GCS between 12 and 9), or severe (GCS less than 8) (Rungruangsak & Poriswanish, 2021). A GCS of 15 is considered normal and entails full consciousness, meaning the individual is alert, oriented, and able to follow commands without any signs of impaired neurological function (Mehta et al., 2019). Although not always accurate, the assessment of severity is essential to prioritise patient management and avoid complications like secondary brain injury if not managed timeously, and to estimate the prognosis of the TBI (Corrigan, Selassie & Orman, 2010; Tenovuo et al., 2021).

In most hospital settings, computed tomography (CT) scans are also commonly employed to assess the structural integrity of the brain and diagnose TBI pathology (Amyot et al., 2015). This radiology technique can also be applied after death as an adjunct to physical post-mortem examination to assess pathological lesions in the brain. Moderate or severe TBIs are serious conditions and can lead to severe outcomes that warrant appropriate neurosurgical intervention such as craniotomies to manage underlying lesions like peridural haemorrhages (Galgano et al., 2017). Unfortunately, the majority of LMICs lack the necessary resources to properly diagnose and manage TBI, leading to severe TBI outcomes in these areas (Ramesh et al., 2014). This is compounded by limited access to neurosurgical services with an overwhelming high population causing significantly low patient-to-neurosurgeon ratios. In Africa, it is estimated that there is one neurosurgeon per 6.36 million individuals compared to an estimated one neurosurgeon per 65,580 individuals in the US (Ramesh et al., 2014).

1.3. TBI epidemiology

1.3.1. Incidence and mortality

Generally, LMICs have shown greater TBI incidence and mortality rates in comparison to HICs. TBI incidence in LMICs was estimated at 150–170 cases per 100,000 individuals compared to 100–120 cases per 100,000 individuals in HICs (Abio et al., 2021; Negida et al., 2021, Dewan et al., 2019). Further, the TBI mortality rate was more than double in LMICs, with an estimated rate of 15.5 per 100,000 individuals compared to 6.8 per 100,000 individuals in HICs (Dewan et al., 2019). Figure 1 below depicts the incidence of TBI across HICs and LMICs as reported by the Global Disease Burden (2019). The USA reported a TBI prevalence of 476 per 100,000 individuals while some LMICs reported much higher prevalences, for example, Burundi (789 per 100,000 individuals), Rwanda (540 per 100,000 individuals) and Mozambique (496 per 100,000 individuals) (Guan et al., 2023). The largest study conducted in SA (Johannesburg), in 1991, reported a TBI incidence of 316 per 100,000 individuals, which is fewer than in other African countries (Nell & Brown, 1991). However, SA's statistics are outdated, and the recent incidence is unknown.

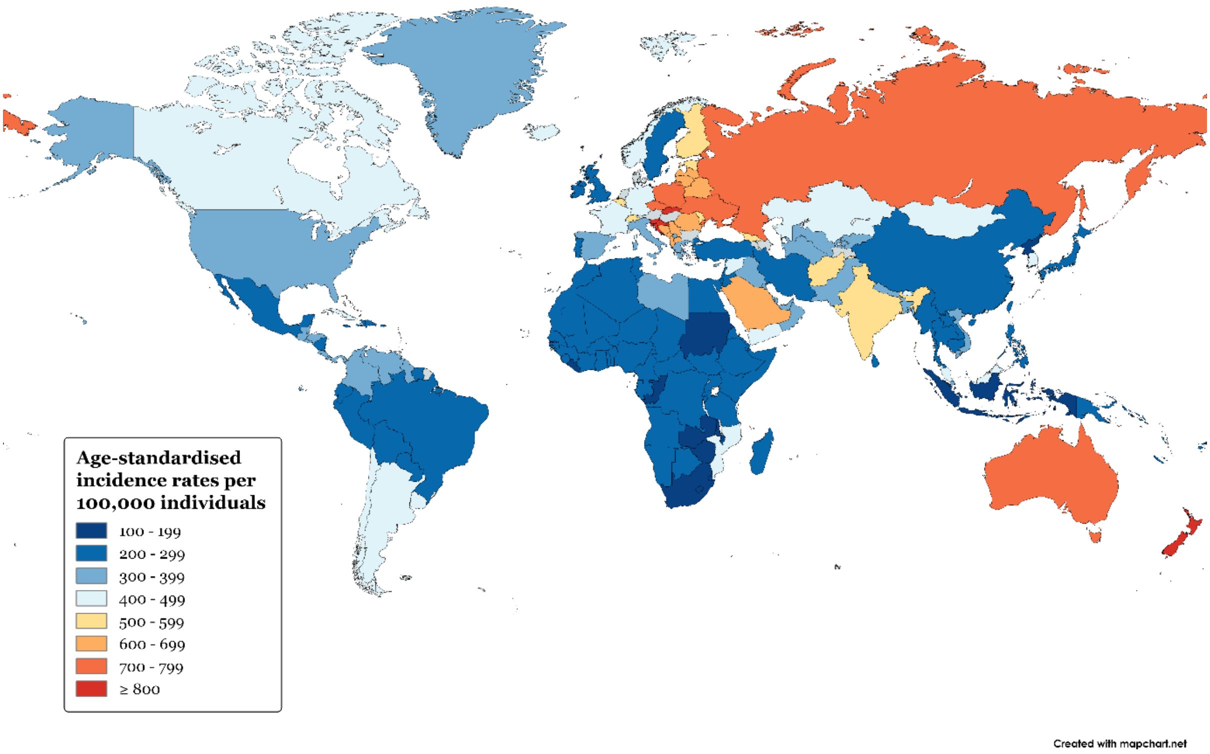


Figure 1: *Global age-standardised TBI incidence rates per 100,000 population (Adapted from source: Guan et al., 2023).*

1.3.2. Sex

Several studies globally have consistently shown a greater male preponderance to TBI morbidity and mortality compared to females (Kavosi et al., 2015; Peeters et al., 2015; Mittal et al., 2020; Algahtany, 2021; Buh et al., 2022). Similar trends were observed in the USA where more males were hospitalised with TBI-associated injuries compared to females. For example, for the main mechanisms of injury of unintentional falls, males (36 per 100,000 individuals) showed high rates in comparison to females (24 per 100,000 individuals). For road traffic collisions, males (23 per 100,000 individuals) had double the rate in comparison to females (11 per 100,000 individuals) (CDC, 2021).

Further, males had a higher rate of TBI-associated fatalities of about 26 per 100,000 which was three times that of females (about 8 per 100,000) (CDC, 2022). Similar trends were also reported in SSA countries with the male preponderance being more than double that of females, for example, in Cameroon and Uganda where 80% of the TBI cases were attributed to males (Zia et al., 2019; Buh et al., 2022). Similarly, in TBI studies focused on children, males still comprised a greater majority of the cases (Schrieff et al., 2013; du Toit-Prinsloo & Saayman, 2014; Dewan et al., 2016; Lack et al., 2021). The observation of male-to-female ratios being more skewed towards the males (i.e., almost double) in children older than 3 years is possibly attributed to boy children partaking in more physically risky play activities than girls (Dewan et al., 2016).

1.3.3. Age

TBI has been shown to have different levels of risk associated with age. Most at risk are children younger than 4 years, adolescents and young adults aged between 15 and 24 years and, elderly individuals greater than 65 years (Galgano et al., 2017).

Several HICs and LMICs have reported high TBI rates in infants and children younger than 4 years, with the former group mainly attributed to falling off furniture that they are placed on (Lack et al., 2021) and RTCs (Dewan et al., 2016). Most of the RTCs in this age group are pedestrian-vehicle collisions reportedly related to lack of parental supervision as children are not fully cognitively developed to interpret traffic signs and to respond appropriately (Lack et al., 2021).

On the contrary, the USA study found that high TBI-associated hospitalisation and fatality rates were reported in individuals aged 15 to 34 attributed to RTCs, and higher rates of 317 per 100,000 and 75 per 100,000 in elderly ≥ 65 years, respectively, in comparison to other age groups (CDC, 2021; CDC, 2022). These high rates in elderly individuals were attributed to unintentional falls with an increase in age being reported as a risk factor (Cusimano et al., 2020). This is potentially because as people get older there are associated physical changes that lead to reductions in muscle mass which affect mobility and balance, as well as the development of health conditions that further lead to the use of medications that affect vision, hearing and balance thus compounding these risk factors and increasing susceptibility to falls (Fu et al., 2017).

In contrast, the LMICs like Cameroon, showed individuals aged between 15 and 45 constituting 75% of the TBI cases but assaults were the leading mechanism of injury (Buh et al., 2022).

Similarly, in SA, individuals aged 25–44 had higher incidence rates for both non-fatal (409 per 100,000 individuals) and fatal TBI (104 per 100,000 individuals) mainly attributed to both assaults and RTCs (Nell & Brown, 1991).

1.3.4. Injury mechanism

Recently, the Global Burden of Disease reported falls (74%) to be the leading injury mechanism for TBI incidence rates followed by road traffic collisions (RTCs) (20%) (Guan et al., 2023). Additionally, falls were reported to be the leading mechanism in many HICs in comparison to LMICs where the leading mechanism was primarily RTCs (Guan et al., 2023). While unintentional falls (29.4 per 100,000 individuals) followed by RTCs (16.6 per 100,000 individuals) were the leading mechanism for TBI-associated hospitalisations in the USA, suicide (7.2 per 100,000 individuals) followed by unintentional falls (4.6 per 100,000 individuals) and RTCs (3.1 per 100,000 individuals) were the leading mechanisms for TBI-associated fatalities (CDC, 2021; CDC, 2022). These trends differ from most SSA countries where RTCs were the leading mechanism of injury, for example, in Mozambique (103 per 100,000 individuals); Ghana (83 per 100,000 individuals) and Cameroon (75 per 100,000 individuals) (Guan et al., 2023).

Currently in SA, the leading mechanism of TBI is RTCs (Guan et al., 2023), however, there has been a change in leading mechanisms over the years. The 1991 study in SA reported interpersonal violence to be the leading mechanism responsible for 51% of non-fatal and 47% of fatal TBIs among Black (African ancestry) individuals and only 27% of non-fatal TBIs were caused by RTCs. This vastly contrasts with 10% of non-fatal and 19% of fatal assault-related TBIs among Whites (European ancestry), with RTCs being the predominant mechanism accounting for 63% of non-fatal TBIs among White individuals. This illustrates a racial disparity in the mechanisms of TBI in the early 1990s in SA (Nell & Brown, 1991; Hyder et al., 2007). However, the profile of the South African demographics has dramatically changed since the early 90s including the end of apartheid, freedom of movement, and economic changes, all of which may have affected the previously reported profiles, highlighting the need for updated data.

As alluded to earlier, recent data from several studies have reported RTCs to be the leading cause of TBIs. In LMICs, this increase in TBI fatalities due to RTCs is attributed to several factors, including urbanisation, the growth of the middle class, the accessibility of less expensive vehicles and motorbikes, and population growth with the lack of an advanced healthcare system (Eaton et al., 2017). Another risk factor for increasing RTCs is impairment due to the influence of alcohol by road users (Weil, Corrigan & Karelina, 2018; Govender et al., 2021). Several studies have reported alcohol consumption to be a risk factor linked to the majority of RTC fatalities (du Plessis, Hlaise & Blumenthal, 2016; Staton et al., 2017; Govender et al., 2021). When consumed, alcohol has been reported to impair judgement and lead to prolonged reaction times. Moreover, reports have indicated that alcohol is linked to heightened risk-taking behaviour such as speeding and reckless driving (du Plessis, Hlaise & Blumenthal, 2016; Nishitani, 2019; Pawłowski et al., 2019) thus, all road users (i.e., motor vehicle occupants, pedestrians, cyclists, and motorcyclists) are at higher risk of RTCs.

Different countries have different legal limits for alcohol concentration for drivers. In SA, according to the *National Road Traffic Act No.93 of 1996*, the legal limit of alcohol is 0.05 grams per 100 millilitres for normal drivers and 0.02 grams per 100 millilitres for professional drivers. A Gauteng (SA) mortuary study found that most of the RTC fatalities with a positive blood alcohol concentration (BAC) had alcohol levels above the legal limit (92.9%), with drivers (60.4%) and pedestrians (55.6%) found to be road users with the most RTC fatalities involving positive BACs (du Plessis, Hlaise & Blumenthal, 2016). The highest BAC levels have been reported in pedestrians. For example, both the Ga-Rankuwa medicolegal mortuary in Gauteng and the Forensic Pathology Services (FPS) in the Western Cape have reported about 50% of RTCs where alcohol was present with the highest mean BACs of greater than 0.25 g/100 mL reported in pedestrians (du Plessis, Hlaise & Blumenthal, 2016). Pedestrians under the influence often exhibit risky road crossing behaviour and impaired judgement thus placing this vulnerable group at a greater risk of RTC-related injuries.

These findings warrant stringent alcohol regulation measures to minimise the risk of fatal RTCs due to alcohol impairment. Most HICs have improved infrastructure on the road which can reduce pedestrian-related RTCs and more stringent policing of driving under the influence. Furthermore, these regions have adequate medical resources and neurosurgical training programmes, which allow for the timeous management of patients who present with TBI. In contrast, in LMICs, there is a scarcity of resources and inadequate numbers of trained clinical professionals which increases the probability of misdiagnosing or less timely management of a progressive injury and could lead to increased mortality, particularly in African countries (Adegboyega et al., 2021).

1.3.5. Socio-economic status

Several studies have reported the association of socio-economic status to TBI through various mechanisms, predominantly RTCs and assaults. A study in Cameroon reported that most of the individuals (65%) who presented with TBI were of low socio-economic status as well as low educational background (76%). The leading mechanisms of injury in the said study were RTCs (85%) and assaults (7.5%) (Buh et al., 2023). Many LMIC regions have no proper road infrastructure and no access to safe transportation (Khan et al., 2020). With RTCs being the leading mechanism of TBIs in these regions, it is these factors that place these individuals at a higher risk for RTC-related injuries. Furthermore, one study reported that children from low socio-economic status were at a higher risk for pedestrian RTCs compared to those from high socio-economic status (Khan et al., 2020). This can be explained by the reality that these children normally rely on walking to travel to school (without supervision) which exposes them to traffic whilst they are not yet fully cognitively developed to interpret and respond to traffic signals (Khan et al., 2020; Lack et al., 2021).

Additionally, a study in Malawi reported a substantial association between unemployment and interpersonal violence, especially among individuals aged 25 to 45. The financial stress due to being unemployed could potentially explain this association. Additionally, individuals from low socio-economic status do not have access to proper medical services to help mitigate the resulting injuries (Khan et al., 2020). This potentially leads to severe TBI outcomes which can ultimately lead to high mortality rates in these regions.

1.4. Effect of the COVID-19 lockdown on TBI epidemiology

With the declaration of the COVID-19 pandemic on 11 March 2020 by the World Health Organization (WHO), many countries implemented restrictive lockdown measures to minimise the spread of the Coronavirus (Manyoni & Abader, 2021). The COVID-19 lockdown as a consequence of the pandemic has been reported to alter overall injury and mortality profiles across different regions (Navsaria et al., 2021). Based on these alterations of injury and mortality profiles, there exists the potential that this event similarly influenced the rates and patterns of TBI.

Several studies across HICs and LMICs have explored this reduction in TBI cases in response to the lockdown (Goyal et al., 2020; Grassner et al., 2021; Karthigeyan et al., 2021; Pinggera et al., 2021; Rault et al., 2021; Rajalu et al., 2022; Bulabula et al., 2023; Leiphart & Leiphart, 2023). Most of these studies have attributed the reduction in TBI cases to the restrictions on mobility and the prohibition of the sale of alcohol (Karthigeyan et al., 2021; Rajalu et al., 2022; Leiphart & Leiphart, 2023). The effect of the enforced restrictions on the sale of alcohol on TBI-associated cases is significant as several studies have reported a substantial correlation between alcohol use and TBI risk (du Plessis, Hlaise & Blumenthal, 2016; Staton et al., 2017; Govender et al., 2021). In countries such as India and South Africa where restrictions were placed on the sale of alcohol, reductions were also observed in the number of TBI cases that were associated with alcohol (Karthigeyan et al., 2021; Rajalu et al., 2022). For example, in India, there was a 4% decrease in TBI cases under the influence of alcohol during the lockdown in comparison to before the lockdown (Karthigeyan et al., 2021).

The leading mechanisms of TBI during the lockdown period were reported to be predominantly assaults and falls (Karthigeyan et al., 2021). The psychosocial stress associated with staying at home may have influenced the spike in assaults as individuals were confined to their homes and most people lost their jobs leading to financial stress further compounding the assaults. Furthermore, the confinement increased the risk of domestic accidents such as falls (Karthigeyan et al., 2021; Rault et al., 2021; Rajalu et al., 2022). A study in Europe reported a 33% reduction in severe TBI cases with an increase in domestic falls (34%) and a decrease in RTCs (32%) during the lockdown (Rault et al., 2021). This study also reported a shift in the sex ratio with the proportion of women doubling during the lockdown possibly due to the decline in RTCs where males were at higher risk. Furthermore, this study also reported a spike in TBI cases under the influence of alcohol with an increase of over 30% during the lockdown. This is consistent with increased alcohol consumption when individuals were confined to their homes in the absence of restrictions on the sale of alcohol in this region (Rault et al., 2021). This increase in alcohol consumption was assumed to have potentially led to an increase in domestic violence against women which would explain the sudden rise in severe injuries reported in more women during the lockdown. In comparison, other studies still reported a high male predominance, for example, in India where the leading mechanism of TBI was still reported to be RTCs although there was a significant reduction of 27.3% in the RTCs cases during the lockdown (Goyal et al., 2020).

In both Europe and India, the median ages of the individuals presenting with TBI remained similar before and during the lockdown with no significant differences (Goyal et al., 2020; Rault et al., 2021). In the USA, however, there was a shift in the mean age from 66.9 years before the lockdown to 73.9 years during the lockdown. This was attributed to the elderly individuals who continued to be at risk of domestic falls whilst the TBI risk was reduced in the younger population as they were confined to their homes and thus there was less exposure to TBI through mechanisms such as RTCs (Leiphart & Leiphart, 2023).

Locally, in SA, Manyoni and Abader (2021) reported a decline in hospitalised TBI-related injuries during the lockdown in March and April 2020 compared to the same period before the lockdown in 2018 (Manyoni & Abader, 2021). During the lockdown in SA, the implemented measures entailed maintaining social and physical distance; restrictions on international, interprovincial, and non-essential travel; prohibition of large gatherings; closure of non-essential facilities and services; and prohibitions on the sale of tobacco and alcohol (Venter et al., 2021). These restrictions on movement are expected to result in fewer RTC fatalities and thus decreased TBI-associated injuries.

A study in SA (Cape Town) highlighted a decrease in RTC injuries during the lockdown and a subsequent increase post-lockdown (Navsaria et al., 2021). Another study conducted at Tshepong Hospital highlighted similar trends where there was a decline in the number of TBI-associated injuries by approximately 66% and a later increase as the lockdown measures were lifted (Bulabula et al., 2023). The leading mechanism of TBI in this study was reported to be interpersonal violence, compounded by the psychosocial stress of being unemployed and being confined at home. The mean age of the affected individuals was 30 years (with a standard deviation of 15.9 years), with a reported high male-to-female ratio of 4:1 (Bulabula et al., 2023). Unlike Tshepong Hospital (Bulabula et al., 2023), in other parts of SA, it remains unknown if TBI rates, especially fatal ones were affected by the COVID-19 lockdown. One study conducted at SRM/OFPI showed that the lockdown period resulted in changes in the overall injury and mortality profiles. This study also assessed the blood alcohol concentrations of the cases that presented to the mortuary during this period and reported lower blood alcohol levels during the highest level of restriction during the lockdown in 2020 compared to 2019 (Bachan, Molefe & Davies, 2023).

All these differences in percentage decrease between different regions are attributed to the different regions implementing different durations, types, and surveillance of restrictive measures during the lockdown. However, it is important to note that globally there was a general decline in TBI cases during the pandemic (Servadei & Cannizzaro, 2021). These findings illustrate the use of a natural phenomenon such as the COVID-19 pandemic in investigating the effects of the implemented lockdown measures in influencing a population's exposure to TBI risk factors and the changes in the mechanistic injury profiles.

1.5. Rationale

This literature review has broadly highlighted the burden of TBI across different regions. However, the current burden of TBI in SA remains under-studied, particularly in the case of fatal TBI. This makes it difficult to understand the epidemiology and associated risk factors for TBI within the South African context. Recent studies in LMICs have reported high occurrences of TBI-associated injuries due to RTCs. Similarly, in 2019, Stats SA reported that RTC fatalities comprised 11% of unnatural causes of death, however, the burden of TBI within this potentially vulnerable group is unknown (Statistics South Africa, 2024.). This is also true for Salt River Mortuary, which has not published recent data on the prevalence of TBI. The only other study to investigate TBI at SRM was conducted 37 years ago (Austen et al., 1987). A previous study found that head trauma constituted 93% of the blunt force homicide cases investigated at SRM over a five-year period (Clark, Mole & Heyns, 2017). TBI could be involved in many of these head trauma cases reported to the mortuary. Therefore, investigating the prevalence of TBI in the mortuary could shed light on the possible burden.

In addition to prevalence, the risk profile of TBI seems to differ across countries and regions with the elderly being more commonly affected in HICs and young adults in certain LMICs. The COVID-19 lockdown was a global event that affected movement and high-risk behaviour and may have potentially influenced TBI risk profile and patterns. This study investigated RTC-related TBI due to the reportedly high RTC fatality rates in several LMICs including SA. This will generate recent RTC-related TBI epidemiological data thus shedding light on the burden of these injuries in a period before and during the national lockdown. It is anticipated that the results can inform the proper planning of the clinical and pathological resources required for the evaluation of TBI due to RTCs in our local environment, as well as guide preventative strategies that can be implemented to reduce the occurrence of RTCs.

1.6. Aims and objectives

1.6.1. Aim

The current study aimed to investigate the epidemiology and patterns of TBI-associated deaths due to RTCs, reported to Salt River Mortuary between 1 January 2019 and 31 December 2020.

1.6.2. Objectives

The objectives were to:

- Identify and review TBI-associated fatalities investigated at SRM over a two-year period.
- Determine the prevalence of TBI-associated injuries due to RTCs that result in unnatural deaths.
- Determine the differences in trends between hospitalised and non-hospitalised cases.
- Compare TBI-associated injury patterns due to RTCs before and during the COVID-19 nationwide lockdown.
- Determine the association of alcohol with TBI-associated fatalities due to RTCs.

Chapter 2: Methods

2.1. Study design

This was a retrospective records review study using autopsy and associated clinical reports of decedents who sustained RTCs and were admitted at Salt River Mortuary over a two-year period, between 1 January 2019 to 31 December 2020. Salt River Mortuary is an M6 academic facility and receives over 3,000 cases a year. It provides services to the West Metropole of the City of Cape Town, divided into the Klipfontein, Mitchells Plain, Southern and Western sub-districts that fall within the SRM drainage area (Figure 2). The Tygerberg sub-district falls outside the SRM drainage area, however, the mortuary occasionally receives cases from this area and thus, it will be considered for the purpose of this study.

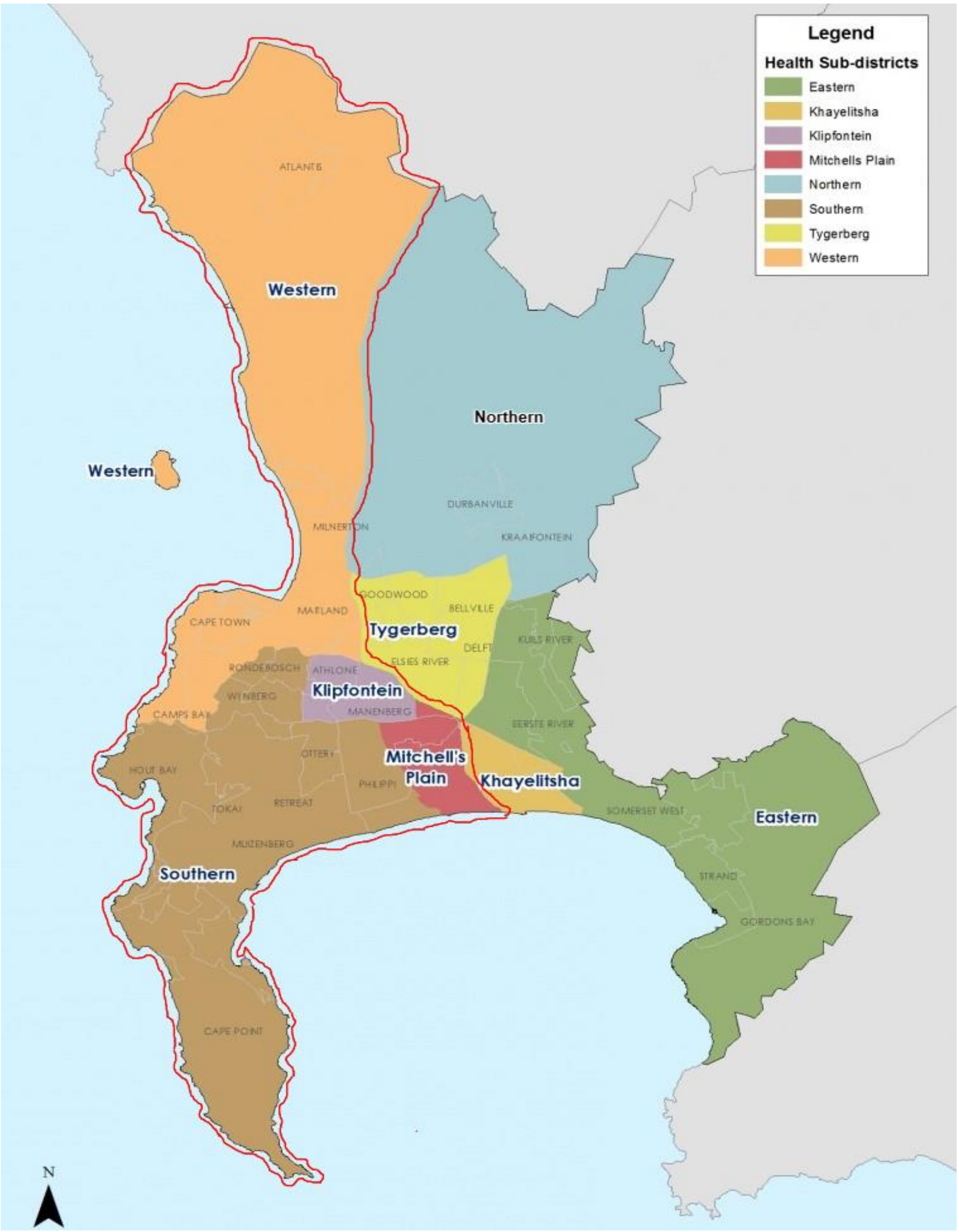


Figure 2: *City of Cape Town West Metropole Health District map with SRM drainage areas outlined.*

2.2. Study population

RTCs were defined as accidents that occurred on the road that involved no less than one moving vehicle resulting in the ultimate death of at least one individual. This definition was inclusive of accidents that involved collisions between two or more vehicles and collisions involving vehicles and pedestrians, cyclists, animals, or fixed objects (such as trees or road infrastructure). The determination of criminal liability amounting to culpable or intentional homicide on the part of the parties involved, as determined by further investigations into any of these deaths was beyond the scope of this study.

The RTC cases were grouped into those that were recorded before (1 January 2019–25 March 2020) and during (26 March 2020–31 December 2020) the COVID-19 nationwide lockdown in SA. Subsequently, within each of these two time periods, the RTC cases were grouped into the TBI-associated group and the non-TBI-associated control group. Briefly, TBI was diagnosed as a traumatic injury to the head which led to alterations in brain function or the presence of brain pathology. The TBI-associated group comprised cases where TBI was documented in the autopsy report regardless of severity, or whether it was the sole or contributing cause of death, based on the findings of the attending pathologist. Conversely, the non-TBI-associated control group included cases that involved RTCs but had no brain injuries documented in autopsy reports, despite the presence of other forms of head trauma, e.g., wounds on the scalp.

2.3. Data collection and management

Data was collected retrospectively from the routine autopsy register completed by forensic pathologists after autopsying decedents admitted at the Salt River Mortuary through an Office Autopsy Database (OAD) (HREC: R036/2014). This database was filtered for cases whose mechanism of injury was recorded as RTCs during 2019 and 2020. This data was supplemented with information from completed autopsy case files to extract the variables relevant to this study. Electronic copies of the case files were obtained via the encrypted digital archival OpenText - content sever™ database, 'Livelink' which is an enterprise content management (ECM) system for Forensic Pathology Services (FPS) in the Western Cape Health Department. When electronic copies were unavailable, data was retrieved from the hard copy autopsy reports archival within the Division of Forensic Medicine and Toxicology (DMFT) at the University of Cape Town (UCT) Faculty of Health Sciences.

Various demographic (e.g., age, sex and, ancestral group) and descriptive variables (e.g., hospitalisation status, location of death, severity of injury) were collected from the autopsy case files (Appendix A). As alcohol intake is a key factor that was tightly regulated during the COVID-19 lockdown and could contribute to the number of TBI cases observed at the mortuary, this study included a validated dataset from a previous study on blood alcohol concentrations in injury-related deaths (Bachan, Molefe & Davies, 2023). This dataset was used to collect data related to the alcohol presence and levels in the decedents.

Four primary sources were used to collect and validate the data of the study subjects recruited from the OAD and further variables required to achieve this study's objectives. The report on medico-legal post-mortem report examination (FPS007) was used to collect information surrounding the autopsy findings and the cause of death. The contemporaneous notes (Lab 27; Appendix B) and the capture scene script (FPS002; Appendix C) were both used to collect the demographic information and details surrounding the scene of the accident. In cases where the decedent was hospitalised before death, the hospital referral form (FPS100; Appendix D) was used to collect information relating to the dates and times of admission till death, the duration and clinical assessment of the severity of the TBI (i.e., GCS scores). If available, hospital records were alternatively consulted to document more clinical history regarding the TBI.

The collected data was collated on a Microsoft Excel® 13 (Microsoft, USA) datasheet and stored on a password-protected external hard drive. This device was retained at access-controlled premises within the DFMT throughout the study period. The data collection and subsequent analysis were performed using the researcher's password-encrypted personal laptop. Unique research identifiers were used instead of the decedent's personal information and any identifying information was not collected but kept confidential. Only the student researcher and researchers on the project had access to the password-protected drive.

Measures were implemented to guarantee the consistency of the data collection process. This was done by validating the cells on the data collection sheet with information from autopsy reports to ensure that the correct data was collected for the different variables.

2.4. Statistical analyses

R version 4.2.3. (R Core Team, 2023) (www.R-project.org) was used for data analysis. Tests for normality (Shapiro-Wilk test) and homogeneity of variances (Bartlett test) were performed. Where data was not normally distributed, the Kruskal-Wallis test for non-parametric data was used to compare continuous data between groups (e.g., age). Frequency distributions were created for categorical data (e.g., type of road user, age category etc.). Pearson's Chi-Square and Fisher’s Exact tests were used to assess the statistical differences between categorical variables. The significance level was set at 0.05 for all tests (Appendix E).

2.5. Ethics

This research study is a sub-study that forms part of a larger study with ethical approval from the University of Cape Town, Faculty of Health Sciences Human Research Ethics (HREC REF: 517/2022). This study proposal was also reviewed and approved by the same committee (HREC REF: 338/2023) (Appendix F). The research conducted in this study followed the Declaration of Helsinki (1964), as updated by the 64th World Medical Association General Assembly in Fortaleza, Brazil, in October 2013 and HREC recommendations. Permission to access the documents and databases used in this study was obtained from Professor Lorna J. Martin, the Clinical Unit Head of Forensic Pathology Services at Salt River Mortuary (Appendix G). Further approval was obtained to link this study to the alcohol-related dataset from a previous study (HREC REF: 751/2020) (Appendix H).

Chapter 3: Results

The prevalence of RTC fatalities at SRM from 2019 to 2020 is indicated in Figure 3. During this period, there was a total of 7694 mortuary admissions. Of these, 8.01% (616/7694) were associated with fatal RTCs.

Of these RTCs, 71.59% (441/616) were recorded before the nationwide lockdown was implemented in SA (1 January 2019–25 March 2020), this accounted for 10.49% (441/4205) of the mortuary caseload during this period. Of these RTCs, 80.95% (357/441) presented with TBI regardless of whether it was the cause of death or not. The remaining 28.41% (175/616) of the RTCs were recorded during the lockdown period (26 March 2020–31 December 2020), this accounted for 5.02% (175/3489) of the mortuary caseload during this period. Of these RTCs, 82.29% (144/175) presented with TBI regardless of whether it was associated with the ultimate cause of death or not.

Overall, there was a decline in RTC-related TBI cases over the study period with 71.26% (357/501) recorded before the lockdown, thus constituting a higher proportion of the study caseload. In contrast, 28.74% (144/501) of the RTC-related TBI cases were recorded during the lockdown period. However, the proportion of TBI cases was not significantly different before and during the lockdown ($p = 0.704$).

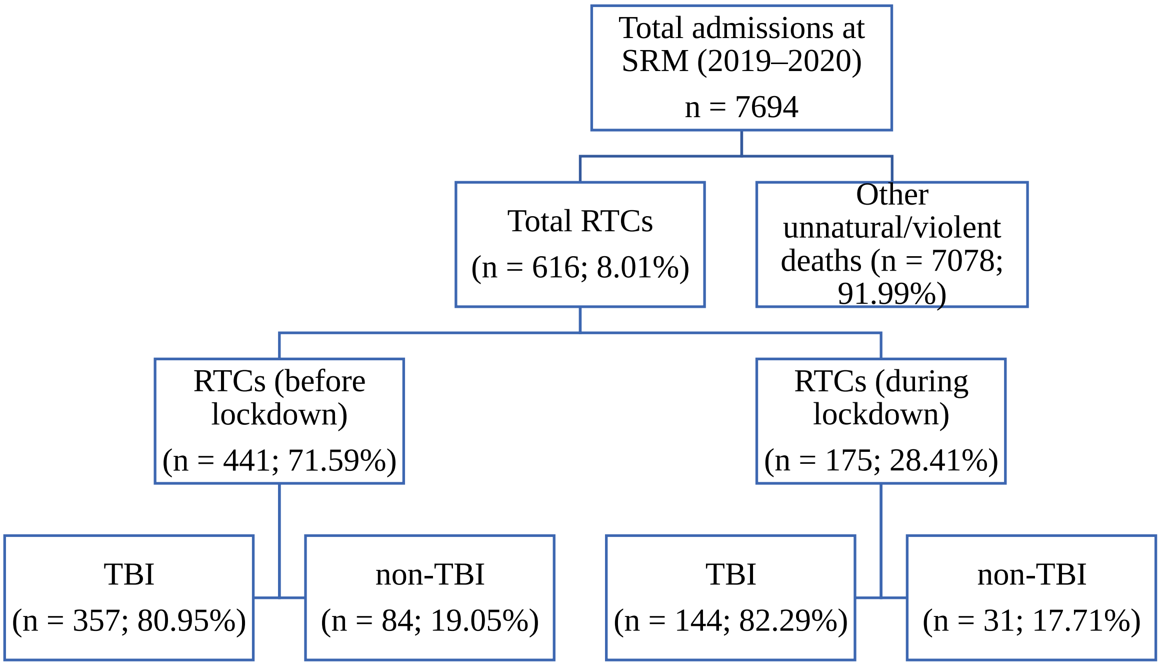


Figure 3: *Distribution of RTC cases before (01/01/2019–25/03/2020) and during (26/03/2020–31/12/2020) the COVID-19 nationwide lockdown.*

3.1. Demographic profile

3.1.1. Sex

Overall, in this study, more males (480/616; 77.92%) were involved in RTCs compared to females (136/616; 22.08%). Among the males, 82.5% (396/480) sustained a TBI and the remaining 17.5% (84/480) did not. Among the females, 77.21% (105/136) sustained a TBI and the remaining 22.79% (31/136) did not, indicating no significant difference between sex and sustaining a TBI or not (p = 0.203).

Similar trends were observed before and during the COVID-19 nationwide lockdown with more males than females. Before the lockdown, 79.14% (349/441) of males were involved in RTCs with 82.52% presenting with TBI compared to 75% of females presenting with TBI. Similarly, during the lockdown, 74.86% (131/175) of males were involved in RTCs with 82.44% presenting with TBI compared to 81.82% of females presenting with TBI, indicating no significant difference between sex and sustaining a TBI or not both before (p = 0.138) and during (p = 1.000) the lockdown.

3.1.2. Age

Overall, the age of the individuals involved in RTCs was widely distributed ranging from 1 to 87 years of age. The median age of the individuals who were involved in RTCs was 35 years, with most of the RTC cases occurring in the 30–39 age category (Table 1). There was a significant difference in the median age between the TBI and non-TBI groups (Figure 4; $p < 0.001$). The individuals in the TBI group were significantly younger (median = 34 years, 95% CI: 32.59–35.4) than those in the non-TBI group (median = 39 years, 95% CI: 35.55–41.34).

The principal age category of the individuals who sustained RTC-related TBI was 20–29 years, with the proportion of individuals presenting with TBI comprising 91.06% (112/123) of the RTC cases within this age category (Table 1). A significant difference was found in the distribution of the age categories between the TBI and non-TBI groups ($p < 0.001$).

Similar trends were observed where there were significant differences in the median ages between the TBI and non-TBI groups before ($p < 0.001$) and during the lockdown ($p = 0.002$). However, there was no change in the median ages across the two groups both before and during the lockdown.

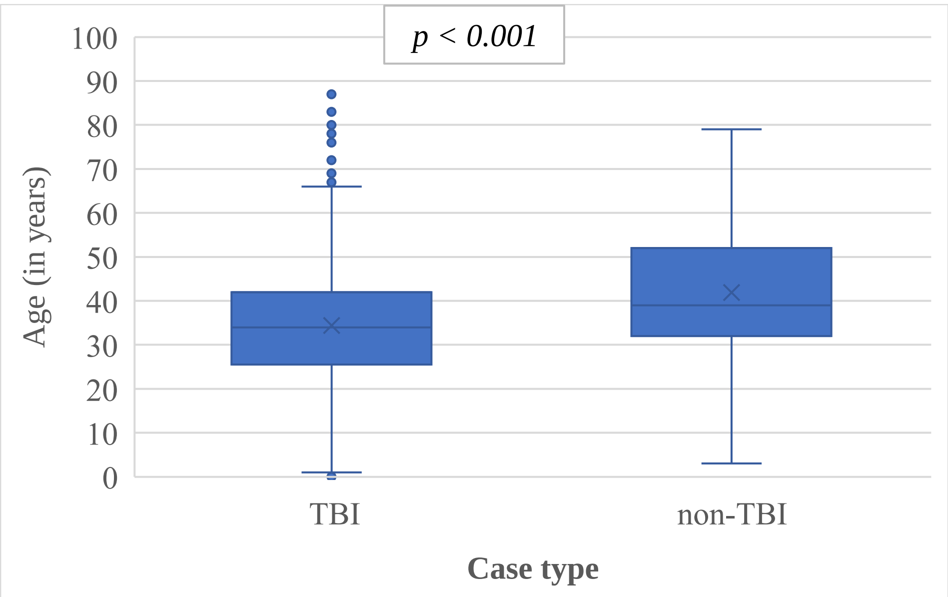


Figure 4: *Distribution of individuals across the TBI and non-TBI groups for all cases by age.*

Table 1: *Distribution of the age categories across the TBI and non-TBI groups.*

Age category	Total cases	Number of TBI cases (% per age category)	Number of non-TBI cases (% per age category)
0–9	40	39 (97.5)	1 (2.5)
10–19	36	30 (83.33)	6 (16.67)
20–29	123	112 (91.06)	11 (8.94)
30–39	204	163 (79.90)	41 (20.10)
40–49	100	77 (77)	23 (23)
50–59	57	39 (68.42)	18 (31.58)
≥ 60	56	41 (73.21)	15 (26.79)
Total	**616**	**501**	**115**

3.2. Behavioural factors

3.2.1. Type of road user

The type of road user involved in the RTC was documented in 615 out of the 616 RTC cases. Overall, there were more pedestrian RTCs compared to other road users (n = 369), followed by drivers (n = 100), passengers (n = 99) and the least number of cases recorded for cyclist RTCs (n = 47). There was a significant difference in the distribution of the types of road users between the TBI and non-TBI groups ($p = 0.023$). Moreover, pedestrians were found to be the road user group with a statistically significant difference compared to other road user groups ($p = 0.036$). However, the proportions of the TBI cases were comparable across all road user groups ranging from 72.7% to 85.1% (Figure 5).

Similar findings were observed before the lockdown where there was a significant difference in the distribution of the types of road users between the TBI and non-TBI groups ($p = 0.044$). Similarly, pedestrians were found to be the road user group with a statistically significant difference compared to other road user groups. The proportion of pedestrians presenting with TBI (84.93%) was higher than the proportions observed in the other groups, however, this was similar to the proportions of other road users presenting with TBI. Similar trends were observed during the lockdown, however, there was no significant difference in the distribution of the types of road users between the TBI and non-TBI groups during this period (p = 0.373).

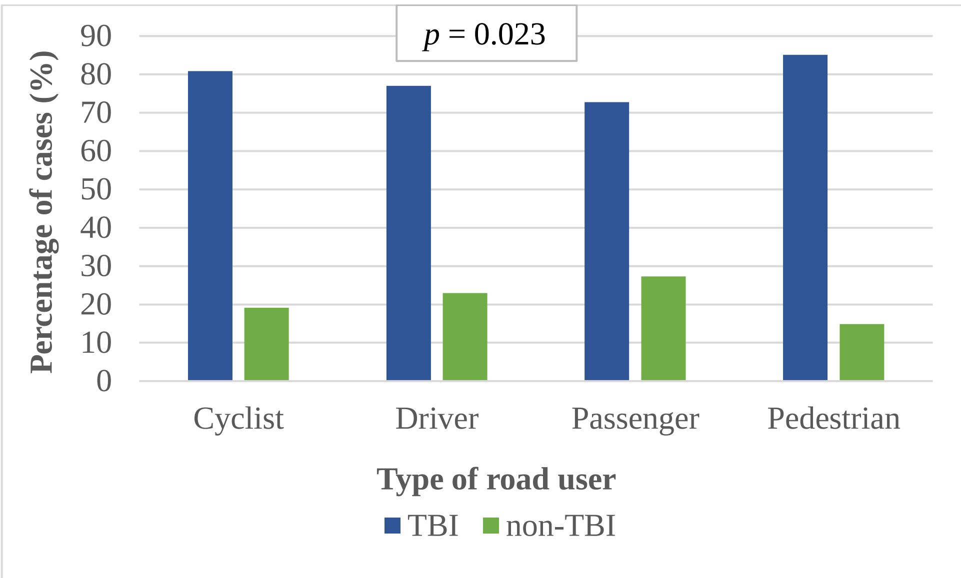


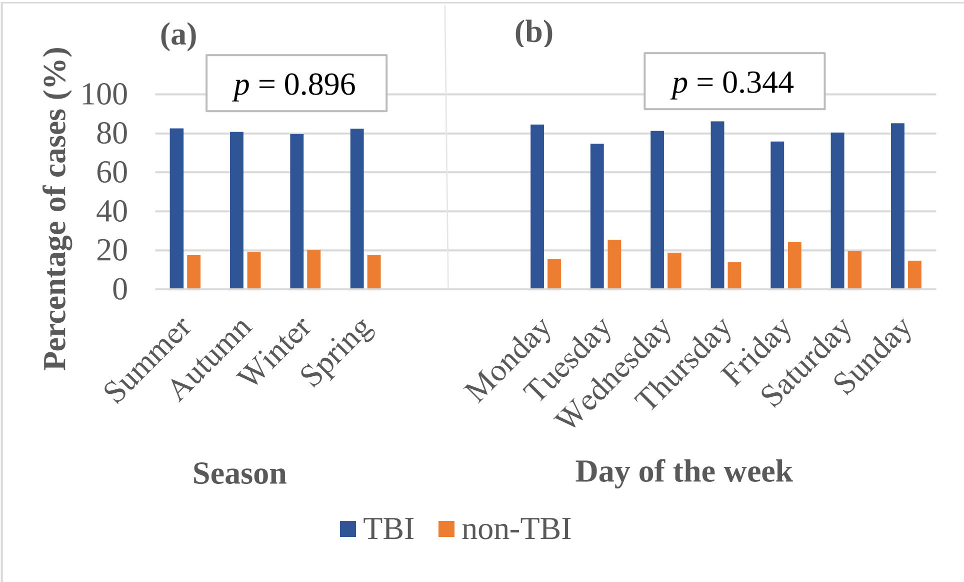
Figure 5: *Distribution of the type of road user across the TBI and non-TBI groups.*

3.2.2. Season and day of the week

Overall, most of the RTC cases occurred during the spring season (182/616; 29.55%), with the proportion of TBI cases being 82.42%. No significant difference was found between the seasons across the TBI and non-TBI groups (p = 0.896). The proportion of TBI cases was slightly higher in summer at 82.48%, however, there was no recognisable pattern between the relative proportion of cases across the TBI and non-TBI groups between the different seasons (Figure 6a).

The number of RTC cases reported throughout the week ranged from 63 to 122. A high number of RTC cases were reported on Monday (n = 84), with a decrease in the reported cases through to Wednesday (n = 64) and a subsequent gradual increase with the highest number of cases reported on Sunday (n = 122). No significant difference was found between the days of the week across the TBI and non-TBI groups (p = 0.344). The proportion of TBI cases remained relatively the same throughout the week with the highest proportion reported on Thursday (86.15%) (Figure 6b).

Similar trends were observed before the lockdown where most RTCs occurred during spring (124/441; 28.12%), with TBI cases comprising 83.87%. In comparison, during the lockdown, most RTCs occurred in winter (76/175; 43.43%), with TBI cases comprising 82.89%. No significant differences were found between the seasons before (p = 0.642) and during (p = 0.429) the lockdown or the days of the week before (p = 0.604) and during (p = 0.132) the lockdown when comparing TBI and non-TBI groups.



Seasonal months in SA: Summer (December–February), Autumn (March–May), Winter (June–August), Spring (September–November).

Figure 6: (a) *Distribution of the different seasons across the TBI and non-TBI groups and* ***(b)*** *Distribution of the different days of the week across the TBI and non-TBI groups.*

3.2.3. Geographical location

Overall, the majority of the RTCs occurred within the Western sub-district (323/616; 52.44%) with 78.64% of the individuals sustaining TBI and the remaining 21.36% sustaining no TBI. The lowest number of RTCs was recorded for the Tygerberg sub-district (5/616; 0.81%), with all the cases presenting with TBI. A significant difference was found between the geographical locations across the TBI and non-TBI groups (p = 0.015). The proportion of RTC cases presenting with TBI was slightly higher for the Klipfontein sub-district at 88.29%. However, there was no recognisable pattern between the relative proportion of the cases per sub-district across the TBI and non-TBI groups (Figure 7). Re-analysis of this data excluding the Tygerberg sub-district (due to low sample numbers) showed similar results with a significant difference observed between the geographical location across the TBI and non-TBI groups (p = 0.010). The relative proportions of the cases per sub-district across the two groups remained relatively similar across the different sub-districts.

Similarly, before the lockdown, most RTCs occurred within the Western sub-district (231/441; 52.38%). Only one RTC case which presented with TBI was recorded for the Tygerberg district (1/441; 0.23%). No significant difference was found between the geographical locations across the TBI and non-TBI groups (p = 0.254) for this period. The proportion of RTC cases presenting with TBI was higher for the Klipfontein sub-district at 85.54%. However, there was no recognisable pattern between the relative proportion of the cases per sub-district across the TBI and non-TBI groups. Re-analysis of this data excluding the Tygerberg sub-district similarly showed no significant difference observed between the geographical location across the TBI and non-TBI groups (p = 0.161).

In comparison, during the lockdown, most RTCs occurred within the Western sub-district (89/175; 50.86%). Only 4 RTC cases that all presented with TBI were recorded for the Tygerberg district (4/175; 2.29%). A significant difference was found between the geographical locations across the TBI and non-TBI groups (p = 0.018). The proportion of RTC cases presenting with TBI was higher for the Klipfontein sub-district at 96.43%. However, there was no recognisable pattern between the relative proportion of the cases per sub-district across the TBI and non-TBI groups. Re-analysis of this data excluding the Tygerberg sub-district similarly showed a significant difference observed between the geographical location across the TBI and non-TBI groups (p = 0.011).

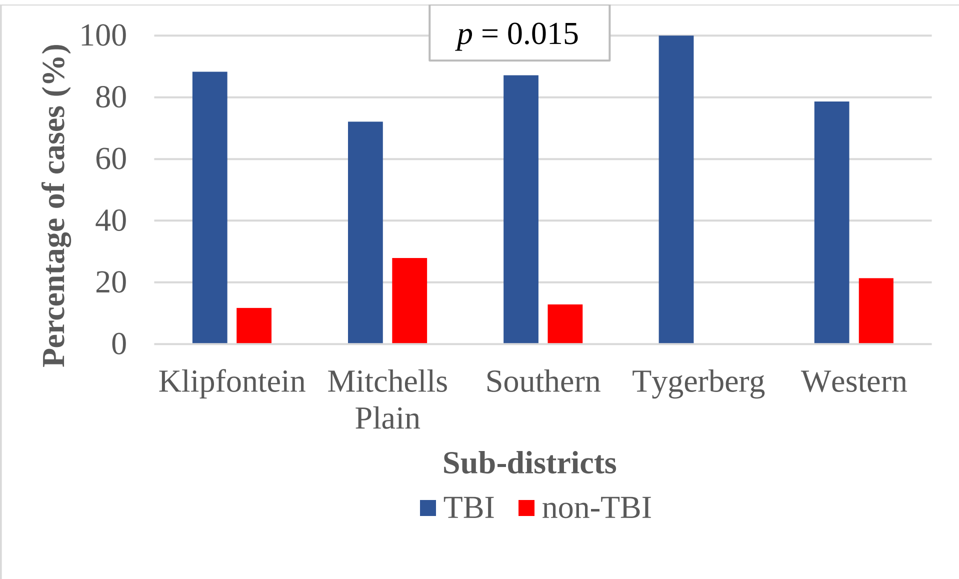


Figure 7: *Distribution of different health sub-districts across the TBI and non-TBI groups.*

3.2.4. Alcohol status

Of the 616 RTCs, alcohol results of were available for analysis in 68.51% (422/616) cases. Overall, most of the individuals (223/422; 52.84%) who sustained RTCs were found to have undetectable alcohol levels of 0 g/100 mL, followed by levels ≥ 0.05 g/100 mL (185/422; 43.84%) and < 0.05 g/100 mL (14/422; 3.32%). The proportion of TBI cases was slightly higher in the group with alcohol levels of < 0.05 g/100 mL at 85.71%, however, there was no recognisable pattern between the relative proportion of cases across the TBI and non-TBI groups between the different alcohol levels (Figure 8). Furthermore, no significant difference was found between the alcohol levels across these two groups ($p = 0.426$).

Similar trends were observed before and during the COVID-19 nationwide lockdown with more RTCs with undetectable alcohol levels followed by those ≥ 0.05 g/100 mL. Before the lockdown, the alcohol group of ≥ 0.05 g/100 mL had a higher proportion of individuals presenting with TBI at 83.45%. In comparison, during the lockdown, the alcohol group of < 0.05 g/100 mL had a higher proportion with all individuals presenting with TBI (100%). However, it is important to note that this group only comprised 6 individuals who all presented with TBI. Furthermore, the relative proportions of TBI cases were comparable across all alcohol levels. Similarly, no significant differences were found before ($p = 0.458$) and during (*p* = 0.664) the lockdown when comparing the different alcohol levels across the TBI and non-TBI groups.

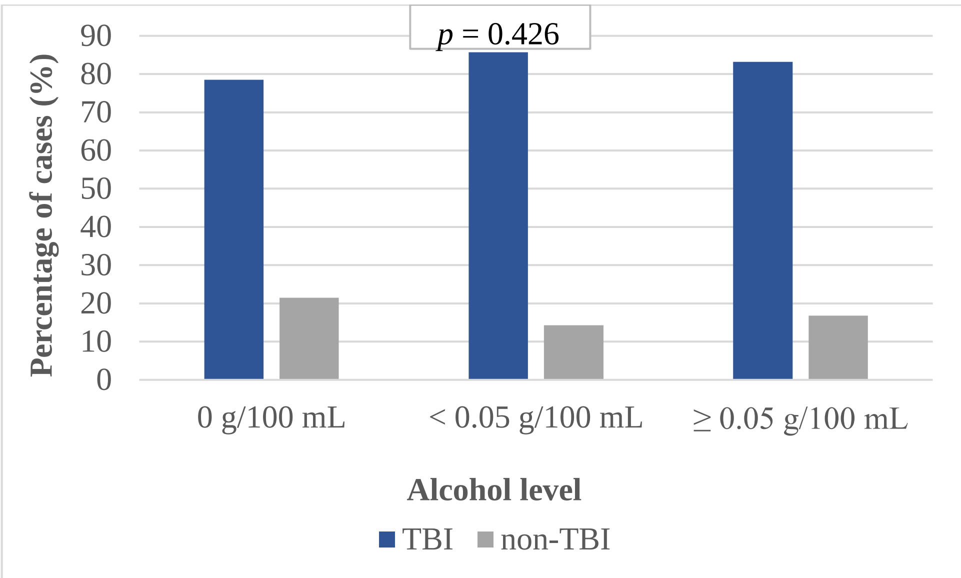


Figure 8: *Distribution of the blood alcohol levels across the TBI and non-TBI groups.*

3.3 Clinical factors

3.3.1. Hospitalisation status

Out of the 616 RTCs, 615 cases had information regarding the hospitalisation status. Of these individuals, 33.82% (208/615) were hospitalised prior to death. The remaining 66.18% (407/615) succumbed to their injuries and died prior to hospitalisation. The proportion of non-hospitalised individuals presenting with TBI (407/615; 82.56%) was higher than that observed for the hospitalised individuals (208/615; 78.85%). However, no statistical significance was found between the hospitalisation status across the TBI and non-TBI groups ($p = 0.314$). Before and during the lockdown, 34.69% and 31.61% of the RTC cases were hospitalised prior to death, respectively. Similarly, there were no significant differences in hospitalisation status between the TBI and non-TBI groups before ($p = 0.392$) and during ($p = 0.765$) the lockdown.

3.3.2. Pathological findings

For the RTC cases where the individuals sustained TBIs, it was found that the most common type of injury was subarachnoid haemorrhages (SAH) recorded in 67.86% (340/501) cases. This was followed by subdural haemorrhage (SDH) recorded in 40.52% (203/501) cases (Table 2). Diffuse axonal injury (DAI) was the least frequent type of injury recorded in 2.4% (12/501) cases. Furthermore, it was found that in 2.4% (12/501) cases, the brain was destroyed, making it difficult to comment on specific injury patterns.

***Table 2**: The frequency of different types of TBI-specific injuries.*

Type of TBI	Number of cases (%)
Subdural haemorrhage (SDH)	203 (40.52)
Epidural haemorrhage (EDH)	15 (2.99)
Subarachnoid haemorrhage (SAH)	340 (67.86)
Intraventricular haemorrhage (IVH)	137 (27.35)
Intracranial haemorrhage (ICH)	91 (18.16)
Raised intracranial pressure (RICP)	13 (2.59)
Diffuse axonal injury (DAI)	12 (2.40)
Cerebral oedema	142 (28.34)
Brain contusion	149 (29.74)
Brain laceration	145 (28.94)
Destroyed brain	12 (2.40)

3.3.3. Injury severity

The severity of the TBI was recorded in 92.02% (461/501) of the cases. In most of these cases (442/461; 95.88%) the TBI was recorded as severe, whilst moderate and mild TBI were recorded in 2.6% (12/461) and 1.52% (7/461) cases, respectively (Figure 9). As expected, most of the individuals who succumbed to their injuries at the scene of the RTC, presented with severe TBI

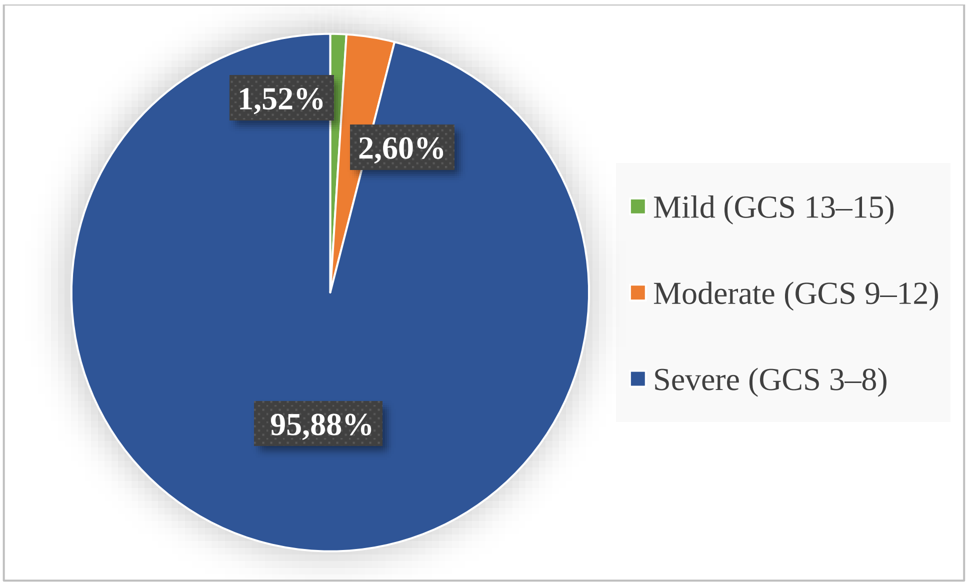


Figure 9: *The distribution of the severity of the TBI.*

Chapter 4: Discussion

This study sought to investigate the epidemiology and patterns of TBI-associated deaths due to RTCs, reported to SRM between 1 January 2019 and 31 December 2020. A total of 616 RTCs was reported, comprising 8.01% of the entire mortuary caseload of 7694 cases admitted during this study period. Of these RTCs, 81.33% of the cases presented with TBI regardless of whether it was the cause of death or not, highlighting a considerable burden of RTC-associated TBI at SRM at 6.51%.

Different regions across LMICs and HICs show variations in the proportion of RTC-related TBIs determined by their mortuary caseloads. In a study conducted in a high-income setting in Saudi Arabia (2010–2019), RTC-related TBI constituted 21.10% (1235/5830) of hospital admissions (Algahtany, 2021). In India, the burden of RTC-related TBIs was reported at 18.91% (287/1518) over a 5-year period (Mittal et al., 2020). In Pretoria (SA), a paediatric study reported fatal head injuries to constitute 1% of the total mortuary caseload (107/11768) in children (≤ 5 years) with 70% of these injuries being attributed to RTCs (du Toit-Prinsloo & Saayman, 2014).

The largest study on TBI published over 3 decades ago in SA reported a fatal TBI incidence of 80 per 100,000, with RTC-related TBIs accounting for 39.17% of the cases (Nell & Brown, 1991). The only comparable study conducted at SRM over 2 years (1983–1985), almost a decade earlier, recorded 8410 total deaths with RTC-related fatal head injuries comprising 2.5% of the caseload (Austen et al., 1987). These findings indicate that there was an increase in RTC-related TBIs over the years, however, they are notably outdated underscoring the need for recent data in this setting to inform recent trends. Nonetheless, these findings undoubtedly highlight the high caseload admitted at SRM/OFPI that remains evident to date and is similar to other LMICs where there are overburdened mortuaries with limited resources (Ramesh et al., 2014).

Furthermore, this study found a general decrease in RTC cases where 71.59% were recorded before the lockdown and the remaining 28.41% were recorded during the lockdown. However, it is crucial to acknowledge that in the context of this study, the period before the nationwide lockdown included 15 months and the period during the lockdown included only 9 months. This would also influence the overall lower number of TBI cases during the lockdown as fewer months were investigated for that period. Nevertheless, the decrease is consistent with the general decrease in RTC cases over this period. This decline can be attributed to the lockdown restrictions on mobility which may have altered travelling patterns and thus the reduction in RTCs due to less travelling. These findings are similar to previous research that found reductions in overall trauma patterns during lockdown (Navsaria et al., 2021; Bulabula et al., 2023).

In this study, the proportion of TBI cases showed no significant differences before and during the lockdown ($p = 0.704$). These findings are consistent with those of a similar study conducted in SA at Tshepong Hospital. The latter study found no significant difference in TBI cases before and during the lockdown, with a minimal 0.75% decrease in the number of cases during the lockdown. Looking at the lockdown levels separately, however, revealed that the highest lockdown level (Level 5) had a 66% decrease in TBI-related injuries, which later increased when the lockdown measures were gradually lifted (Bulabula et al., 2023). Unlike the previous study, our study did not investigate the trends of TBI cases across the different lockdown levels in SA as it was outside the scope of this study hence, the variations across the different lockdown levels cannot be reported.

Our study results suggest that while there is a strong association of TBI with RTCs, these brain injuries were not significantly affected by lockdown measures. These findings indicate that TBI management must be prioritised even during pandemics. Public health policies must continuously emphasise road safety measures and, ensure adequate resources are strategically allocated to emergency care and trauma services. This principle is crucial in any scenario where healthcare systems face increased strain, ensuring that effective TBI care and safety protocols are maintained to manage injuries effectively.

4.1. Demographic profile

Overall, in this study, more males (77.92%) sustained RTC fatalities than females (22.08%). The risk of TBI between the two sexes was almost comparable, with males at 82.50% and females at 77.21%. Similar studies across different HICs and LMICs have shown a greater male preponderance for TBI (Kavosi et al., 2015; Peeters et al., 2015; Tran et al., 2015; Eaton et al., 2017; Buh et al., 2022; Teh et al., 2023). A systematic review conducted in Europe on 28 studies on TBI, found that there was an overall male predominance of TBI in all the reviewed studies (Peeters et al., 2015). In three referral hospitals in Cameroon, there were 6248

TBIs recorded with males (80%) comprising a large portion of these cases compared to females (20%) (Buh et al., 2022). Similarly, in Iran, more males (86%) died due to RTC-related TBIs compared to females (14%) (Kavosi et al., 2015). Similar trends are also reported in studies focussed on TBIs in children (Schrieff et al., 2013; du Toit-Prinsloo & Saayman, 2014; Lack et al., 2021). There were more male children (64.96%) than females (35.04%) with severe TBI in a study conducted at a children's hospital in Cape Town (SA) (Schrieff et al., 2013).

In our study, the male preponderance for TBI still prevailed both before and during the lockdown which was also reported in other similar studies (Goyal et al., 2020; Karthigeyan et al., 2021; Pinggera et al., 2021; Bulabula et al., 2023). However, one study in Europe noted a shift in the sex ratio with the proportion of women doubling during the lockdown possibly due to the decline in RTCs where males were at higher risk (Rault et al., 2021). Since the current study was only focused on RTC-related TBIs, the male preponderance before and during the lockdown is explained by the fact that more males are generally at a higher risk for RTCs than females, regardless of lockdown restrictions.

The male predominance observed from our study may typically be explained by the fact that generally, SRM receives a higher caseload of males than females annually. This could be linked to the high-risk behaviour commonly observed in males and other gender roles which expose males to environments that predispose them to sustaining injuries (Krebs et al., 2017). Furthermore, other behavioural factors such as driving under the influence of alcohol & drugs and reckless driving, such as speeding, have been reported to be more prevalent in males compared to females (Krebs et al., 2017; Ambunda & Lourens, 2022).

This study reported individuals in the TBI group (median = 34 years, 95% CI: 32.59–35.40) to be significantly younger ($p < 0.001$) than those in the non-TBI group (median = 39 years, 95% CI: 35.55–41.34). Studies across different regions in HICs and LMICs have shown associations between different age groups and mechanisms of injury. Falls have been reported to be the most common injury mechanism in children and elderly individuals whilst RTCs have been reported to be the most common injury mechanism in young adults (Peeters et al., 2015; Galgano et al., 2017), consistent with our findings.

Particularly, young men between the ages of 20–40 years have been reported to have high non-fatal TBI rates in association with behavioural factors such as risk-taking, driving under the influence and reckless driving (Krebs et al., 2017). Saudi Arabia reported a mean of 26.16 ± 16.27 years for RTC-related TBI (Algahtany, 2021). Comparably, the mean age of TBI patients in Malawi was reported to be 28.8 ± 16.3 years (Eaton et al., 2017). In Malaysia, the mean age was 32.4 ± 13.7 years for RTC-related TBI admissions (Teh et al., 2023). In India, the most common age category that was vulnerable to RTC-related TBI was 20–30 years comprising 28.96% of the fatalities (Mittal et al., 2020). These distinctions in age are important for targeting prevention initiatives (Peeters et al., 2015).

In our study, the median ages of the individuals in the TBI and non-TBI groups remained the same before and during the lockdown, with the TBI group being significantly younger than the non-TBI group. Similar studies focusing on TBI have also shown no significant changes in the mean ages reported for these two periods. In Europe, the mean age of the TBI patients showed no significant differences before (34.1 ± 18.9) and during (33.2 ± 17.9) lockdown (Karthigeyan et al., 2021). In contrast, another study showed a shift towards an older demographic of patients presenting with TBI possibly attributed to younger age groups being at a lesser risk due to the restrictions, whilst the older population was still susceptible to domestic fall-related TBIs (Leiphart & Leiphart, 2023).

4.2. Behavioural factors

This study reported more pedestrian RTCs (60%), followed by equal proportions of drivers and passengers at 16.23% and 16.07%, respectively. Similarly, recent data in the SA showed that the Western Cape province had the highest number of pedestrian deaths due to RTCs over 10 years from 2007 to 2017 (Statistics South Africa, 2024). This was further supported by reports from the FPS which reported pedestrians to comprise over 40% of the RTC-related fatalities in the Western Cape (Western Cape Government, 2017). These findings are consistent with the reports across different regions with respect to the road users most likely to encounter an RTC. Most studies, especially in LMICs have reported pedestrians to be the most frequent road users to encounter RTCs. Furthermore, the current study found that the proportion of TBI cases was slightly higher (85.09%) for pedestrians, however, this was comparable to other road user groups. This shows that there is no association between TBI risk and road user types, all are equally likely to sustain TBI in an RTC.

In contrast, a study in the United Kingdom (UK), found that pedestrians and cyclists were six times more likely to sustain moderate and severe TBIs compared to drivers and passengers (Baker et al., 2022). Comparably, in Gambia pedestrians and cyclists were reported to be three times more likely to sustain TBIs in comparison to drivers and passengers (Sanyang et al., 2017). Because many people in LMICs lack access to transport, walking is their major mode of mobility, which contributes to the high incidence of pedestrian deaths in these areas. Consequently, these individuals are regularly subjected to traffic on roads with inadequate infrastructure designed to safeguard this vulnerable group of road users. Moreover, pedestrians are particularly vulnerable since they frequently live in informal areas near busy roadways in urban areas, which puts them at risk for RTCs (Sukhai, Govender & Niekerk, 2021; Bantjes et al., 2024). All these factors could potentially explain the high pedestrian RTC fatalities also observed in the Western Cape. It is crucial to note that although the current study found no particular association between the different road user groups and the risk of sustaining a TBI, pedestrians accounted for more than half of the RTCs. These findings still warrant targeted approaches to ensure the safety of these individuals to reduce the incidence of RTCs thus ensuring an overall reduction in the TBIs that could result.

Unlike the general population, paediatric studies on TBI show an association with road-user type with child pedestrians most likely sustaining RTC-related TBIs followed by passengers (Schrieff et al., 2013; Lack et al., 2021). Numerous paediatric studies have revealed a similar pattern of increased pedestrian mortality, which is ascribed to children's inability to read traffic signals and respond effectively, leaving them exposed to RTCs (Lack et al., 2021). A South African state hospital study performed over a 5-year period showed that pedestrians accounted for 80% of all the RTC cases that led to TBI, followed by passengers (17.5%) and instances when children fell out of moving vehicles comprised 2.5% of the cases (Lack et al., 2021). Another study (2006–2011) conducted in a South African state children's hospital, showed that 54.74% of the RTC-related TBIs were sustained by pedestrians followed by passengers (21.17%) (Schrieff et al., 2013). This is an issue, especially in LMICs where many children walk to school every day and are therefore frequently exposed to traffic thus, further emphasising the need for targeted interventions to protect these vulnerable groups.

Some studies investigated the distribution of RTC-related TBI cases across different seasons and days of the week. This study found that the highest number of RTC cases (29.55%) were recorded in spring. Our findings are consistent with a Gauteng study which found that most RTCs (27%) were recorded in spring with the majority of the RTC fatalities occurring over the weekend (du Plessis, Hlaise & Blumenthal, 2016) however, this study did not look at TBI. In our study, the proportion of TBI cases was found to be slightly higher (82.48%) in summer although this was comparable across all seasons. Furthermore, this study demonstrated an increase in the number of RTC cases at the start of the week followed by a decrease and a later increase towards the weekend with more cases reported on Sunday (19.87%). However, the proportion of TBI cases remained relatively similar throughout the week. In a children's study in Cape Town (SA), more TBI injuries occurred over the weekend, and this was attributed to the fact that children were off-school during these days and thus would be exposed to environmental hazards (i.e., cars on the roads) (Schrieff et al., 2013). A study in Saudi Arabia reported high RTC-related TBI cases in the summer (37.30%) compared to the other seasons and a particularly higher number during weekdays (70.90%) compared to weekends (29.1%) (Algahtany, 2021). However, this study further alluded that the relation between these variations over different seasons and days of the week was non-significant (Algahtany, 2021). These findings are consistent with the current study's findings which warrants a more consistent approach aimed at reducing TBI risk regardless of the season or day of the week.

This study reported that almost half of the RTCs (52.44%) occurred in the Western sub-district with the Tygerberg sub-district recording the lowest number of cases (0.81%). However, the proportion of individuals presenting with TBI was the highest in the Tygerberg sub-district and this was because there were only 5 RTC cases from this region and all the individuals presented with TBI. This low number of cases from this sub-district can be explained by the fact that SRM occasionally receives cases from this sub-district as it falls outside the SRM drainage area, and the cases will normally be reported to the Tygerberg FPS. Similarly, the high number of cases from the Western sub-district could be attributed to the fact that the regions in this sub-district are serviced by the SRM thus most RTCs would be reported to this facility. There was a significant difference in the geographical location across the TBI and non-TBI groups ($p = 0.015$). A further re-analysis was conducted excluding the Tygerberg sub-district, yielding a relatively similar significant difference in the geographical location across the two groups ($p = 0.010$). This was done to provide a more accurate representation of the population served by SRM, however, in this instance, these similar findings indicate that the initial result is not affected by the outlier nature of the Tygerberg sub-district. These findings were also consistent when analysing the periods before and during the lockdown, with the exclusion of Tygerberg.

The proportion of TBI cases was slightly higher in the Klipfontein sub-district (88.29%), however, this was comparable with the other sub-districts. This indicates that there should be interventions to improve road infrastructure and safety in all areas as well as accessibility to efficient trauma services that will aid TBI management, especially, in low-income areas where individuals often succumb to their injuries because of inaccessibility to timeous TBI management services.

Many countries have reported a high occurrence of alcohol-impaired driving which results in RTCs (du Plessis, Hlaise & Blumenthal, 2016; Staton et al., 2017; Weil, Corrigan & Karelina, 2018; Govender et al., 2021). In this study, out of the 422 individuals where alcohol analysis was performed, the majority (52.84%) were found to have undetectable alcohol levels. For the remaining individuals where alcohol was detectable (47.16%), the majority (92.96%) had an alcohol level of ≥ 0.05 g/100 mL and the remaining 7.04% had an alcohol level of < 0.05 g/100 mL. These findings are consistent with the study in Gauteng that reported 92.9% of the RTC cases to have alcohol levels ≥ 0.05 g/100 mL (du Plessis, Hlaise & Blumenthal, 2016). This indicates an area of concern as a great majority of road users are found to have alcohol levels above the stipulated legal limit in SA (du Plessis, Hlaise & Blumenthal, 2016). This raises the need for more stringent regulatory measures to ensure that all road users adhere to stipulated alcohol limits with more focus on pedestrian safety as this group encountered the majority of the RTCs.

Furthermore, the current study found that the proportion of TBI cases was similar between the different alcohol levels. These findings were also observed before and during the lockdown, where most individuals had alcohol levels above the legal limit however, the proportion of the TBI cases was relatively similar across all alcohol level groups. This indicates that there was no association between alcohol consumption and sustaining a TBI. Keeping in mind that alcohol leads to impaired judgment, these findings warrant more targeted approaches against drunk driving. This involves raising awareness of the risks of driving under the influence, as well as enforcing tighter regulations against drunk driving to reduce RTCs as well potential TBIs that could result. Similarly, these interventions also need to be targeted at pedestrians as impairment due to alcohol places them at higher risks for RTCs and thus the resulting injuries.

4.3. Clinical factors

There seems to be a consensus reported in numerous studies where SAH is the most prevalent type of brain injury. The reasons thereof are unknown but thought to be because the thinner blood vessels within the subarachnoid space rupture during the mechanism of injury wherein the brain moves relative to the fixed skull as would occur during RTCs, falls or assaults.

Accordingly, in the current study, SAH was recorded in 67.86% followed by SDH which was recorded in 40.52% of the TBI cases. Understandably, SDH is caused by the same acceleration-deceleration mechanism of injury which commonly causes tearing of the bridging veins with resultant SDH. DAI was recorded in only 2.4% of the TBI cases. In this study, the brain was sent for neuropathological and histological examination which confirmed DAI in 1 case out of the 12 cases with suspected DAI. This type of brain injury has been reported to be common after an individual has sustained a high-velocity RTC, falls from a considerable height as well as in cases of severe assaults. Furthermore, histological examination has been reported to be a successful method of assessing this type of brain injury post-mortem (Al-Sarraj, 2016). However, this was not frequently done in the current study and may have accounted for the lower proportion of this type of injury.

In India, the most common type of injury reported was SAH (82%) followed by SDH (76%) with the least common type of injury being IVH (14%) for fatal TBI (Chourasia, 2017). Similarly, another study conducted at a tertiary hospital in Tunisia (over a 4-year period) reported SAH in 75.8% of the ICU (intensive care unit) cases followed by cerebral contusion (74.2%), DAI (49.3%) and SDH (45.2%) (Chelly et al., 2019). The relatively high DAI proportion compared to our study can be explained by the fact that this study was conducted at a hospital and utilised a CT scan and MRI (magnetic resonance imaging) to assess the pattern of brain injuries. These methods can efficiently diagnose DAI much more accurately in hospital settings. Additionally, in Pretoria (SA), a study on fatal TBIs in children below 5 years reported SAH to be the most common type of TBI recorded in 72% of the cases followed by SDH (36%) and the least common type of injury being EDH recorded in 4.6% of the cases.

The current study also found that in 2.4% of the TBI cases, the brain structure was destroyed with little to no brain matter available to fully assess the pattern of injuries sustained. Moreover, two-thirds (66.18%) of individuals died before hospital admission (died at the scene of the accident, on the way to the hospital or were pronounced dead on arrival) while a third (33.82%) who sustained RTCs were hospitalised. These findings highlight the destructive nature and fatality risk of RTCs in some cases. Additionally, this high pre-hospital mortality can also be attributed to the slower response times of the emergency medical services reported in many lower socio-economic areas (Koome et al., 2022). Furthermore, these areas are frequently located distances away from hospital facilities leading to a further increase in pre-hospital deaths (Zaidi et al., 2019), further emphasising the need for accessible and timeous trauma services in these areas.

Generally, there seems to be a high number of mild TBIs reported in different studies in comparison to moderate and severe TBIs. In contrast, our findings indicated a higher percentage of severe TBI cases (95.88%), followed by moderate (2.6%) and mild TBI (1.52%). This could be due to a greater proportion of this category comprising individuals who died at the scene of the accident before being taken to the hospital and thus the GCS score was classified as poor. Contrarily, some hospital-based studies in LMICs have reported higher mild TBI rates, followed by severe and moderate TBI. In Malaysia, a study focusing on RTC-related TBI over an 11-year period (2009–2019) reported a prevalence of mild TBIs at 34.8%, followed by severe (34.0%) and moderate TBI (23.1%) (Teh et al., 2023). In Malawi, over an 8-month period, mild TBI was reported in 43.5% of the cases, followed by severe (33.0%) and moderate TBI (24.3%) (Eaton et al., 2017). Additionally, a study in Cameroon reported a mild TBI prevalence of 51.4%, followed by moderate (31.5%) and severe TBI (7%) (Buh et al., 2022). In another South African study focusing on TBI in children below 10 years over a 5-year period, mild TBIs accounted for 87% of the cases, followed by severe (7%) and moderate (6%) TBIs (Lack et al., 2021). Although most studies differ in the distribution of moderate and severe TBIs, there seems to be an overall higher rate of mild TBIs recorded across most hospital-based studies (Tenovuo et al., 2021). In contrast, the current study observed a low prevalence of mild TBIs because this study utilised mortuary-based data and thus most of the TBIs were fatal. This indicates the underrepresentation of mild TBI cases in mortuary settings and emphasises the potential for future studies to look at both hospital and mortuary data for a more informative analysis.

4.4. Limitations of the study

The current study employed a retrospective study design examining autopsy reports and ancillary documentation. Relying on secondary data meant the inability to control the quality of the data captured. As such, in some cases, demographic information (e.g., race) was missing or not recorded, or in some instances, was designated as unknown.

Additionally, interpreting the results of this study must consider inconsistencies in the level of detail of brain injury patterns and clinical status (GCS scores) available in the autopsy and clinical records respectively. In some cases, autopsy reports varied in the use of pathological terminology and extent of detail in describing brain injury patterns making it challenging for the researcher to collect information related to TBI pathology. In these cases, including where there was ambiguity, assessment of the original report by the experienced forensic pathologists in the study team provided clarity to categorise those injury patterns. Where certain injuries were expected but not mentioned, for example, in a case of brain contusions with SDH described but no SAH was reported, it was assumed that this injury was indeed absent. Correlating such neuropathological autopsy findings with radiological findings would be most appropriate in such cases but would be equally limited in this study as 66.18% of cases died before hospitalisation and therefore lacked radiology investigation. Obtaining radiological reports which are not routinely archived as part of post-mortem records was beyond the scope of this study.

The finding of a very low prevalence of mild TBI (1.52%) in this study must be interpreted with caution as firstly, this study utilised mortuary data which implicitly means most cases would have sustained fatal TBI as the sole cause or in combination with other injuries causing death, leading to sampling bias. Additionally, accurate assessment of mild TBI requires the brain to be fixed and assessed after formalin fixation, with or without histopathological examination of selected areas of the brain. This is important to acknowledge, as the pathological assessment of mild TBI is often missed if the brain is examined in the fresh state, and while fixing such brains is strongly recommended as international best practice, it is not mandatory.

Additionally, this study assessed the alcohol concentration levels reported for the decedents to elucidate the possible role of intoxication in RTC-related TBIs. The choice to collect samples for alcohol analysis was at the prerogative of the attending forensic pathologist. Alcohol analysis may not be requested for various reasons including in children below the age of 18 years, or cases where there was initial survival of a few hours in hospital, but this is variable amongst pathologists. Furthermore, the alcohol results included in this study were interpreted as reported by an independent laboratory and not validated for this study, while in some cases the results were still outstanding at the time of analysing this data possibly related to delays due to the high mortuary caseloads impacting on the laboratory outputs. Thus, the prevalence of alcohol intoxication reported in this study may be affected. However, this is an expected reality in most LMICs considering the overburdened medical system with current backlogs in state labs further exacerbating this issue. This highlights that there needs to be prompt analysis performed and issuing of toxicology/chemistry reports timeously.

Lastly, the unequal distribution of months before (15 months) and during (9 months) COVID-19 lockdown may have affected the prevalence rate of variables assessed in these respective periods. Furthermore, for the one-third of the cases that were hospitalised before death in this study, there was insufficient information collected for hospital-related variables. In many of these cases, the hospital referral form (FPS100) did not provide enough information such as the GCS scores and duration of hospitalisation. This negatively impacted the amount of data available for statistical analysis. Future studies should consider including a combination of both mortuary-based and hospital-based data to collect sufficient information regarding clinical status details.

4.5. Conclusion and recommendations

The findings from this study highlighted the most recent burden of TBI at SRM/OFPI which is one of the two busiest mortuaries in Cape Town. These findings show a TBI mortality of 6.51% attributed to RTCs over a two-year period, before and during the COVID-19 lockdown. This is worrying and possibly represents the tip of the iceberg as TBI can be caused by other violent mechanisms like assaults and falls. This underscores the need for more studies to generate a comprehensive TBI database to understand its overall burden.

This study explored two time periods, before and during the lockdown in SA, which have shown the potential to alter injury patterns globally in previous studies. Within the SA context, the various restrictions on mobility and alcohol consumption enforced have been shown to alter overall trauma patterns, thus, potentially altering TBI patterns resulting from RTCs as there was restriction on movement. Similarly, this study also demonstrated a reduction in the number of fatal RTCs during the lockdown, and fewer alcohol-related RTCs during this period, emphasising the need for more stringent measures and regulations against driving whilst under the influence of alcohol in addition to movement restrictions. However, the proportion and severity of TBI cases before and during the lockdown remained the same suggesting no potential for lockdown measures to benefit TBI prevalence rates or outcomes.

This study has reported an overall high percentage of severe, mostly fatal TBIs due to RTCs. This indicates the need to implement effective prevention strategies to eliminate incidents of RTCs, which are reportedly high in SA, as the most effective intervention to prevent RTC-related TBIs. Equally, this study highlighted the need for proper clinical diagnoses and management of TBI of the small proportion of patients who survive long enough to reach emergency centres in the hospitals, to further prevent fatalities from TBIs. In SA, as in many LMICs, there are limited resources and insufficiently trained neurosurgeons, which although posing a great challenge to managing patients' TBIs, the lower number of surviving patients may be helpful in resource planning and allocation. Furthermore, this study found that there was a high proportion of RTC cases with alcohol above the legal limit. Thus, it is recommended that more stringent measures and harsh punishment be implemented to regulate traffic and deter those driving under the influence of alcohol. This has the potential to reduce overall RTCs and thus the number of TBI cases which may be sustained otherwise.

If appropriately documented, accurate hospital records may help provide an accurate assessment of the true burden, severity and prognosis of RTC-related TBI, assist in informing pathological correlation of brain injury patterns and further inform resource allocation for emergency clinicians, neurosurgeons, radiologists and pathologists. Any full understanding of epidemiological trends and outcomes on TBIs will require a full database with accurate and complete demographic, death scene, autopsy, and clinical data accessible to researchers. Forensic Pathology Officers (FPOs) who consistently capture demographic data should be trained on the value of this information and encouraged to update records whenever such information becomes available at the mortuary, even if this occurs much later than the post-mortem date. Equally, clinicians and forensic pathologists must attempt to agree on standardised ways (e.g., using standardised templates with agreed minimum reporting fields) of reporting the clinical status and neuropathological findings in patients and decedents with TBI. This may minimise the need to invest in data capturers and encourage researchers to participate in TBI epidemiological research which remains a public health priority.

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Appendices

Appendix A: Variable table for data collection

Table A1: List of variables collected from the autopsy case files.

Variable	Type of variable	Method of Data Capture
Date of death	Numerical discrete	yyyy/mm/dd
Date of injury	Numerical discrete	yyyy/mm/dd
Age (in years)	Numerical continuous	Range 0–100+
Sex	Categorical binary	Drop-down list: - Male - Female - Unknown
Ancestral group	Categorical nominal	Drop-down list: - White - Black - Mixed (SA Coloured) - Indian/Asian - Unknown
Location of death	Categorical nominal	Drop-down list: - Bucket/bin - Darn - Hospital - House - Lake - Open land - Railway track - River - Road - Sea - Shack - Shebeen - Swimming pool - Toilet - Other
Day of the week	Categorical nominal	Drop-down list: - Monday - Tuesday - Wednesday

		- Thursday - Friday - Saturday - Sunday
Season	Categorical nominal	Drop-down list: - Summer - Autumn - Winter - Spring
Geographical location (sub-district)	Categorical nominal	Drop-down list: - Klipfontein - Mitchells Plain - Southern - Tygerberg - Western
Cause of death	Categorical binary	Drop-down list: - TBI-associated - non TBI-associated
Manner of death	Categorical nominal	Drop-down list: - Accident - Suicide - Homicide - Unknown
Mechanism of death	Categorical nominal	Free text – as reported by the pathologist
Brain contusion	Categorical binary	Drop-down list: - Yes - No
Brain laceration	Categorical binary	Drop-down list: - Yes - No
Cerebral oedema	Categorical binary	Drop-down list: - Yes - No
Concussion	Categorical binary	Drop-down list: - Yes - No
Deep scalp bruising	Categorical binary	Drop-down list: - Yes - No
Destroyed brain	Categorical binary	Drop-down list: - Yes - No

Diffuse axonal injury	Categorical binary	Drop-down list: - Yes - No
Epidural haemorrhage	Categorical binary	Drop-down list: - Yes - No
Facial fracture	Categorical binary	Drop-down list: - Yes - No
Facial/scalp contusion	Categorical binary	Drop-down list: - Yes - No
Facial/scalp laceration	Categorical binary	Drop-down list: - Yes - No
Intracerebral haemorrhage	Categorical binary	Drop-down list: - Yes - No
Intraventricular haemorrhage	Categorical binary	Drop-down list: - Yes - No
Raised intracranial pressure	Categorical binary	Drop-down list: - Yes - No
Subarachnoid haemorrhage	Categorical binary	Drop-down list: - Yes - No
Subdural haemorrhage	Categorical binary	Drop-down list: - Yes - No
Skull fracture	Categorical binary	Drop-down list: - Yes - No
Severity of injury	Categorical nominal	Drop-down list: - Mild (GCS between 13 and 15) - Moderate (GCS between 9 and 12) - Severe (GCS less than 8) - Unknown
Person injured	Categorical nominal	Drop-down list: - Driver - Cyclist

		- Pedestrian - Passenger - Unknown
Hospitalisation status	Categorical binary	Drop-down list: - Hospitalised - Non-hospitalised - Unknown
Hospital	Categorical nominal	Drop-down list: - False Bay - Groote Schuur - Lentegeur - Life Vincent Palloti Private - Milnerton Medi-Clinic - Mitchells Plain Hospital - Red Cross - Tokai Melomed - Other
Duration of hospitalisation	Categorical nominal	Drop-down list: - less than 24 hours - 1 to 2 days - 3 to 4 days - 5 to 6 days - 7 to 13 days - 14 to 20 days - 21 to 27 days - 28 days or more
Alcohol presence	Categorical binary	Drop-down list: - Yes - No - Unknown
Alcohol level (in g/100 mL)	Numerical continuous	Number – as reported by the toxicology report

Appendix B: Contemporaneous notes (Lab 27)

CONTEMPORANEOUS NOTE (LAB. 27) : SALT RIVER FORENSIC PATHOLOGY LABORATORY

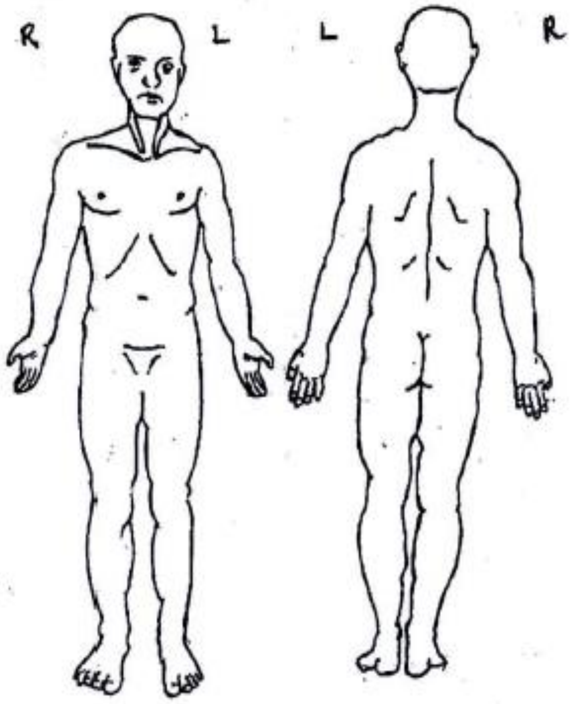
WC/11/____________ PATHOLOGIST ________________ BODY BAG SEAL NO ________________

ASSISTANT ____________________ DATE OF PM ________________ TIME OF PM __________

1. RACE: White | Coloured | African | Asiatic
2. GENDER: Male | Female
3. AGE: ______________
4. NAME OF DECEASED: ______________________
5. AREA OF DEATH: ______________________
6. SAPS STATION: ______________________
7. DATE OF DEATH: ______________________
8. TIME OF DEATH: ______________
9. DIED IN:

House	Shack	Road	Dam	River
Swimming pool	Bucket / Bin	Shebeen	Sea	Lake
Hospital	Railway track	Open land	Toilet	Other

HISTORY ______________________________



EXTERNAL FEATURES ______________________________

CHIEF POST-MORTEM FINDINGS

1.
2.
3.
4.
5.

CAUSE OF DEATH ______________________________

ALCOHOL SEAL NUMBERS Received by:	Inner	Outer
Exhibits received by:		
Photographer:		

Signature: ____________________

WC/11/...

1. HEIGHT WEIGHT PHYSIQUE NUTRITION
2. IDENTIFYING FEATURES

TEETH	R	M	M	M	PM	PM	C	I	I	I	I	C	PM	PM	M	M	M
	L																
	R	M	M	M	PM	PM	C	I	I	I	I	C	PM	PM	M	M	M
	L																

3. PM Changes: Rigor Mortis: Arms/Legs/Mandible Lividity
Temperature
4. External Appearance
5. Skull
6. Brain Brain Mass:
7. Eyes: Ears: Nose:
8. Mouth, tongue and pharynx
9. Neck
10. Thoracic cage
11. Mediastinum
12. Airways
13. Lungs Mass: R
Mass: L
14. Heart Mass:
15. Large blood vessels
16. Peritoneal cavity
17. Stomach Contents
18. Intestines
19. Liver Mass:
20. Pancreas Mass:
21. Spleen Mass:
22. Adrenals Mass: R
Mass: L
23. Kidneys Mass: R
Mass: L
24. Bladder Urine: Clear/turbulent/blood-stained
25. Pelvic Walls
26. Genitalia: <u>MALE:</u> EXTERNAL PENIS:- Circ/uncirc. SCROTUM INTERNAL: Testes Prostate
<u>FEMALE:</u> External Internal Uterus/Ovaries
27. Spinal Column
28. Spinal Cord

<u>SPECIMENS RETAINED</u>
1. Blood/Eye Fluid for alcohol Outer seal: Inner seal:
2. Toxicology Outer seal: Inner seal:
3. Histology

<u>ADDITIONAL SPECIMENS:</u>
1.
2.
3.
4.

Appendix C: Capture scene script (FPS002)

FPS002

Western Cape Government
Health

Forensic Pathology Service

FPS CASE DETAILS

FPS LABORATORY ______________ BODY REF. NO. ______________

FORENSIC OFFICER ______________

INCIDENT DETAILS

PARTICULARS OF DECEASED

ALLEGED NAMES ______________

ALLEGED SURNAME ______________

RACE ______________ GENDER ______________ AGE ______________

ALLEGED OCCUPATION ______________

SCENE ADDRESS:

BUILDING ______________

STREET ______________

SUBURB ______________ CITY ______________

GPS COORDINATES ______________

MANNER OF DEATH:

CATEGORY ______________ TYPE ______________

SPECIAL CIRCUMSTANCES ______________

TIME RECORDING:

	ALLEGED DEATH BODY DISCOVERED	CALL RECEIVED	ARRIVED ON SCENE	DEATH DECLARATION	BODY RECEIVED	DEPART FROM SCENE	ARRIVE AT FACILITY
DATE							
TIME							

TISSUE DONATION:

DO THE FAMILY OBJECT TO BE CONTACTED REGARDING TISSUE DONATION [YES] [NO]

CONTACT PERSON:

FULL NAMES ______________

ADDRESS ______________

RELATION TO DECEASED ______________ TEL/CELL ______________

INVESTIGATION DETAILS STATION ______________ CAS ______________

INVESTIGATOR PARTICULARS:

FULL NAMES ______________ DESIGNATION ______________ PERSAL ______________

ORGANISATION ______________ CONTACT NO ______________

SUPPORT

EXHIBITS RETAINED: (RETAINED BY FPS STAFF ON SCENE)

DESCRIPTION	SEAL

FORENSIC EVIDENCE RETAINED BY SAPS

DESCRIPTION	SEAL

SAMPLES TO BE COLLECTED: (REQUIRED BY SAPS FOR FURTHER ANALYSIS)

DESCRIPTION

FPS 004: PROPERTY OF THE DECEASED: (RECEIVED BY FPS STAFF)

DESCRIPTION	SEAL

OFFICIAL RECEIPT

AUTHORISED PERSON HANDLING OVER | FPS STAFF MEMBER RECEIVING

FULL NAMES | FULL NAMES

PERSAL | PERSAL

SHOOTING

ALLEGED WEAPON (MAKE) ______________________ CALIBER __________

NO OF INDIVIDUAL WEAPONS SUSPECTED __________ WEAPON/S FOUND AT SCENE? YES NO ?

NO OF GUNSHOT WOUNDS ON THE BODY __________ WERE ANY INTERMEDIATE TARGETS HIT BEFORE THE BODY? YES NO ?

SPECIFY INTERMEDIATE TARGET ______________________

OUTERMOST LAYER OF CLOTHING ______________________

WERE ANY BULLETS/OTHER PROJECTILES RECOVERED ON SCENE BY SAPS / ICD? YES NO ?

HOW MANY? __________

HANG, STRANGLE, SUFFOCATE

LIGATURE OR DEVICE FOUND YES NO ? PROPERTIES ______________________

SUSPENSION POINT ______________________ HEIGHT __________ cm

ROAD TRAFFIC ACCIDENT

ROLE IN ACCIDENT ______________________ NO OF FATALATIES __________

TYPE OF VEHICLE ______________________ NO OF VEHICLES __________

TYPE OF ROAD ______________________ ROAD CONDITION ______________________

WEATHER CONDITIONS ______________________ SPEED LIMIT __________ km/h

POSITION OF BODY ON SCENE ______________________

STABBING

ALLEGED WEAPON ______________________ WEAPON AT SCENE YES NO ?

NO OF VICTIMS ______________________ NO OF INDIVIDUAL WEAPONS SUSPECTED __________

SEXUAL ASSAULT

ANY SIGNS OF STRUGGLE? YES NO ?

STATUS OF CLOTHING ______________________

CLOTHING FOUND NEAR BODY ______________________

UNDERWEAR FOUND? YES NO ?

WHERE FOUND IN RELATION TO BODY?

FLUID FROM VAGINA? YES NO ?

WAS A SPECIALIST FORENSIC PATHOLOGIST / GENERAL PRACTITIONER ON THE SCENE? YES NO ?

GENERAL SCENE INFORMATION

HAS THE BODY BEEN MOVED? YES NO ?

IF SO, WHAT WAS THE ORIGINAL POSITION OF THE BODY? ______________________

ADDITIONAL NOTES

____

____

____

____

____

____

Appendix D: Hospital referral form (FPS100)

Western Cape Government

FPS100
Forensic Pathology Service
Confidential report on suspected unnatural deaths

GUIDELINES FOR THE COMPLETION OF THE REPORT OF SUSPECTED UNNATURAL DEATHS
PLEASE NOTE THE FOLLOWING:

1. This form must be completed in **DETAIL** for all deaths where the **cause of death is unnatural**. The **reason for suspecting an unnatural cause of death** and a **suspected cause of death MUST** be completed.
2. This form must be completed **legibly**.
3. Guidelines for good quality note-keeping applies to this document.
4. For procedure-related deaths, this form should be completed in addition to the form **GW7/24**.
5. **Natural deaths are not admitted to Forensic Pathology Service (FPS).**
6. This document has to be completed by a **SENIOR CLINICIAN** involved in the treatment of the patient. It is the duty of the senior clinician to complete these forms **as soon as possible after death.**
7. The complete form, together with the **hospital folder** of the patient, must accompany the body to the referred FPS Laboratory.
8. **No bodies will be removed from the hospital** without the completed documents and the complete hospital folder of the patient, including X-rays, CT scans etc. Results of all special investigations should be included in the patient folder.
9. Delay in the completion and submission of the form will, therefore, cause a delay in the completion of the medico-legal autopsy and will create an unnecessary inconvenience to the families. After completion of the autopsy, all patient information (patient folder, surgical notes, results, X-rays, CT scans) will be returned to the hospital or family member of the deceased, should this be appropriate.
10. **Surgical notes** are imperative in cases referred to as procedure-related deaths. Private medical practitioners must provide these additionally.
11. **Typed referrals** can also be provided.
12. This document is **constructed as an affirmation**. The original copy will be sent with the autopsy report to be included in the **SAPS investigation docket** to be used in legal proceedings. Competent completion of this document will prevent unnecessary court appearances.
13. **Do not complete the DHA-1663 (death notification form)**, as this will be completed after the post-mortem examination has been conducted. **Only complete a declaration of death form. The original declaration of death form is to accompany the body.**
14. If there is any **uncertainty or query** regarding the referral of a case, **contact** your local **FPS** Laboratory.

CLASSIFICATION OF UNNATURAL DEATHS:

1. **Deaths due to the application of violence and the complications thereof**
    a. Physical, chemical and thermal violence
    b. Injury caused by nature, e.g. dog bite, bee sting anaphylaxis
    c. Complications due to injury
        i. Tetanus/rabies after a dog bite
        ii. Gas gangrene/necrotizing fasciitis after gunshot wounds, stab wound etc.
        iii. Pneumonia/pulmonary embolism after traumatic injury
2. **Procedure-related death (Health Professions Act, Section 56)**
    a. Definition: Death of a person undergoing or as a result of a procedure of a **therapeutic, diagnostic or palliative nature** or of which **any aspect** of such a procedure has been a contributory cause shall not be deemed to be a death of natural causes.
    b. There is **no time limit to the definition** (not limited to 24-hours after the procedure).
    c. Includes all forms of medical and surgical procedures such as tooth extractions, cardiac catheterization or bronchoscopy.
3. **Sudden Unexpected Deaths**
    a. The so-called 'cot deaths' (SIDS).
    b. Sudden unexpected and/or unexplained deaths without any obvious cause of death.
4. Any death, including deaths that would otherwise be classified as being 'natural' where it is suspected that the death was due to an act of omission or commission by any other person or medical staff.

If the space provided is not enough, ADDITIONAL PAGES can be added. Patient details must be on EVERY additional page AND the pages numbered.	
Additional pages added: ☐ Yes ☐ No	Number additional pages:

WC/__________/_______________/_______________

AFFIRMATION IN TERMS OF THE MEDICO-LEGAL DEATH INVESTIGATION

I NAME AND SURNAME (CAPITAL LETTERS) ______________________________ **(FULL NAMES)** am registered with the Health Professions Council of South Africa as a medical practitioner **MP** ________________. The information supplied regarding the deceased, whose name is provisioned hereunder, is to the best of my knowledge and belief a true reflection of the medical care of the patient.

Patient details or hospital sticker		
Full name:		
Patient number:		
DOB or Age:		
Gender:	☐ F	☐ M

Admission date:	dd/mm/yyyy
Admission time:	
Date of death:	dd/mm/yyyy
Time of death:	

NOTE THE FOLLOWING:

Do not remove any signs of medical intervention from the body (e.g. vascular lines, ET tubes, catheters). Do not disconnect and remove drainage and urine bags.

Do not alter or modify wounds by medical or surgical means. If there is no alternative, wounds must be clearly documented.

Document the following:

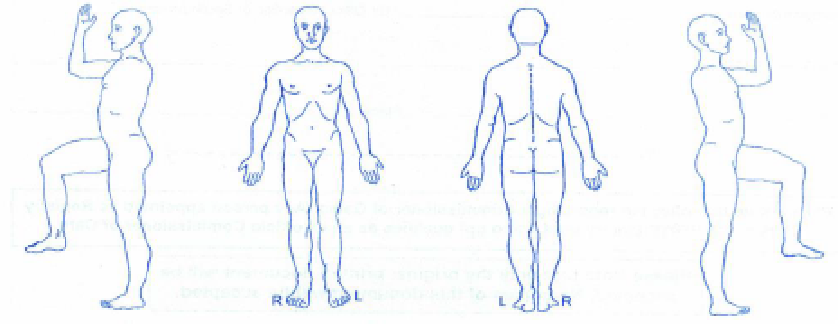
1. **Removal and disposal of any foreign bodies from the body, e.g. bullets.**
2. The administration of blood products and the volume transfused.

Reasons for suspecting unnatural deaths: (refer to page 1/4 for the classification of unnatural deaths)

MANDATORY

Describe the medical history and initial clinical findings on admission. Indicate injuries on the diagrams below.

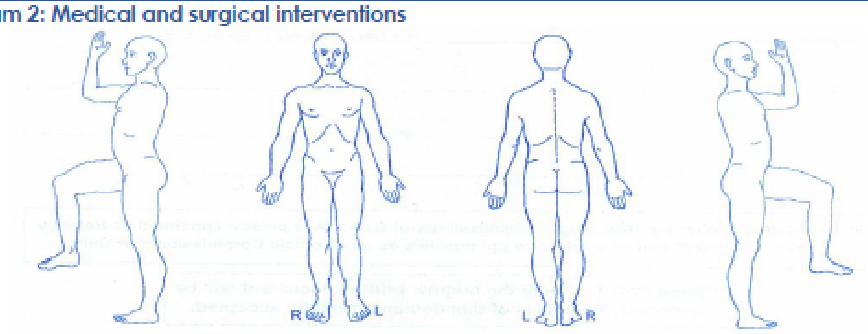
Diagram 1: Wounds/injuries



Describe the clinical course in chronological order: (Add pages if needed)

Medical and surgical interventions: Specify **ALL** surgical and medical procedures performed on the patient. Indicate the intervention sites on the diagrams below, e.g. chest drain site, vascular catheter placement, surgical incisions etc. **Provide surgical notes with FPS100.** Provide details on **ALL** medication/drugs administered during hospital. **(Add pages if needed)**

Diagram 2: Medical and surgical interventions



WC/____________/____________________/____________________

Have specimens been obtained for laboratory tests?				Yes	No	Laboratory name here				
Does the patient have any of the following suspected or confirmed diseases?										
COVID-19	Yes	No	Hepatitis	Yes	No	HIV	Yes	No	Tuberculosis	Yes / No
Other	Include any relevant laboratory results here									
Add pages if needed.										
Was any of the following taken in the hospital? If YES, provide the results in the space given.										
Alcohol	Yes	No	Drugs/Toxicology	Yes	No	Laboratory name here				
Add pages if needed.										
Clothing	Yes	No	Please provide FPS with the clothing if the death is due to ballistic or sharp force trauma.							
Sexual Assault Kit	Yes	No	Kit number							
Weapon	Yes	No	Type of weapon			Seal number				
Bullet/s	Yes	No	Number			Seal number				
Indicate the position of the bullet/s in the space provided or in diagram 1.										
Add pages if needed.										
Suspected cause of unnatural death: (for clinicopathological correlation)	MANDATORY									

I hereby confirm that the facts described above are true to the best of my knowledge and belief and that I make this declaration knowing that, if it is tendered in evidence, I will be liable for prosecution if I willfully state anything which I know to be false or which I do not believe to be true.

Signature of deponent:	
Designation:	
Qualifications:	
Deponent's address:	
Cell phone number:	MANDATORY
Email address:	OPTIONAL

I certify that the deponent has acknowledged that he/she knows and understands the contents of the above declaration, which was affirmed before me, and the deponent's signature was placed thereon in my presence.

Full names and surname: (CAPITAL LETTERS)			
Signature:			
Designation (rank): Ex Officio Republic of South Africa			
Name of employer:			
Business address:			
Date:		Place:	

Please note the following regarding Commissioner of Oaths: Any person appointed as Registry Clerk in the WCG (salary level 4 and up) qualifies as an Ex Officio Commissioner of Oath.

PLEASE NOTE THAT ONLY THE ORIGINAL PRINTED DOCUMENT WILL BE ACCEPTED. NO COPIES OF THIS DOCUMENT WILL BE ACCEPTED.

Appendix E: Statistical tests

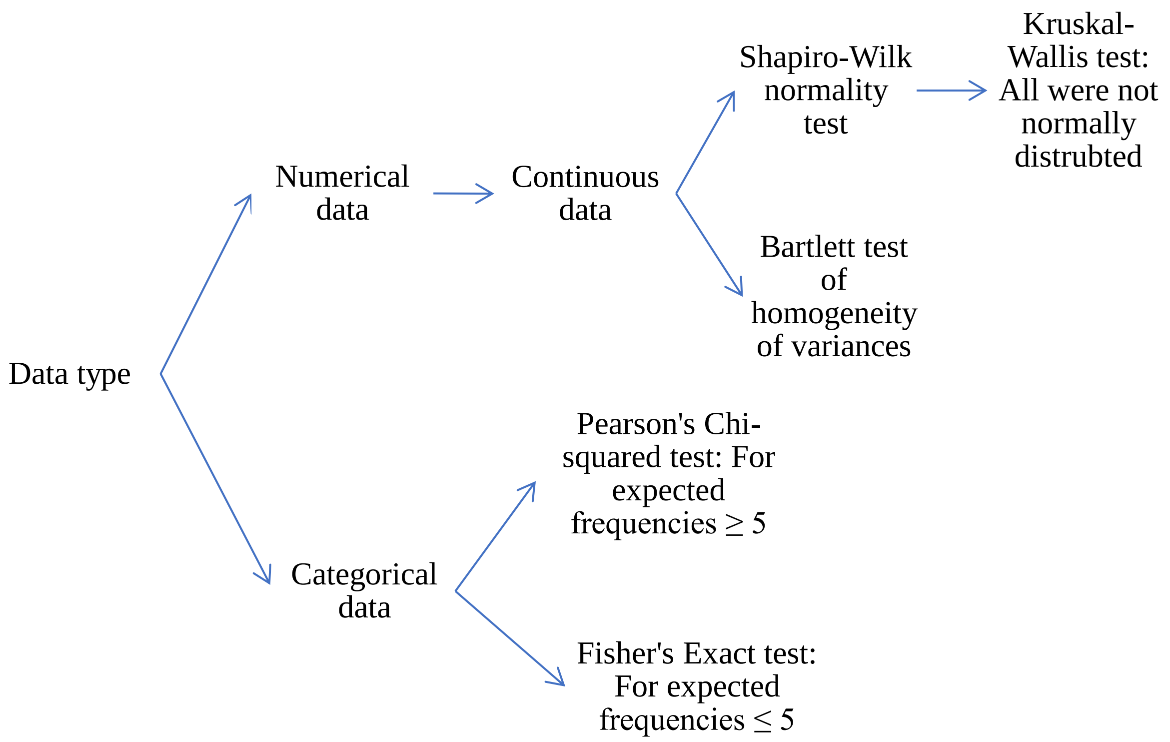


Figure E1: Summary flow diagram of the statistical tests employed in the analysis of data.

Appendix F: HREC approval letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room 45 E-52-E-Floor- Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/home/human-research-ethics

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29 May 2023

HREC REF: 338/2023

Dr S Abrahams
Division of Forensic Medicine & Toxicology
Entrance 3 Level 1 Falmouth Building- FHS
Email: shameemah.abrahams@uct.ac.za
Student: mkgmah013@myuct.ac.za

Dear Dr Abrahams

PROJECT TITLE: EFFECT OF THE COVID-19 NATIONAL LOCKDOWN ON TRAUMATIC BRAIN INJURY FATALITIES AT SALT RIVER MORTUARY: A RETROSPECTIVE REVIEW 2018 - 2021- SUB-STUDY LINKED 517/2022-
(MASTER'S DEGREE-MS MAHLATSE MOKGOTHO)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 May 2024.

Please submit a progress form, using the standardised Annual Report Form (FHS016) if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

The HREC acknowledge that the student: Ms Mahlatse Mokgotho will also be involved in this study.

Please quote HREC REF 338/2023 in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE

HREC/ref 338.2023

Federal Wide Assurance Number: FWA00001637. Institutional Review Board (IRB) number: IRB00001938 NHREC-registration number: REC-210208-007
This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use: Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2020), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix G: SRM OAD access approval letter

Western Cape Government
Health
FOR YOU

DIRECTORATE: Forensic Pathology Service
ENQUIRIES: Professor LJ Martin MB BCh *Wits* Dip For Med *SA*
M Med Path (Foren) *UCT* F C For Path *SA*
Email: lornaj.martin@uct.ac.za

To whom it may concern,

I, Lorna J. Martin, do hereby grant final permission for the following researchers to have access as specified for the research project as stipulated:

Principal Investigator: Dr Shameemah Abrahams
Staff number: 01443782

Researcher: Mr Calvin Mole
Staff number: 01444082

Researcher: Dr Itumeleng Molefe
Staff number: 01434093

Researcher: Ms Mahlatse Mokgotho (MSc student)
Student number: mkgmah013

Researcher: Ms Cameron Timm (Honours student)
Student number: tmmcam001

Project Title: Retrospective study on the trends associated with fatalities resulting from traumatic brain injury in Salt River Mortuary

Access to:

✓	The autopsy allocations
✓	The Office Autopsy Database and related records
	Forensic Pathology Services Laboratory, Salt River for observation and collection of data
	Forensic Pathology Services Laboratory, Salt River for the collection of tissue samples
	Forensic Pathology Services Laboratory, Salt River for conducting Interviews
	Forensic Pathology Services Laboratory, Salt River for obtaining informed consent

For the data collection period of 01/01/2023 to 31/12/2023

pp

Professor Lorna J. Martin *(Signature)*
Head of Division
Division of Forensic Medicine and Toxicology

25/05/2023

Date *(dd/mm/yyyy)*

Approved

Ms V Thompson *(signature)*
Director
Forensic Pathology Service: WCGHW

2023/08/28

Date *(dd/mm/yyyy)*

Division of Forensic Med
Faculty of Health S
Anzio Road, Obser
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Fax: +27 21 448 1249
www.forensicmedicine.uct.ac.za

"Our Mission is to be an outstanding teaching and research university, educating for life and addressing the challenges facing our society."

Appendix H: Alcohol dataset approval letter

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Human Research Ethics Committee

E52 Room 46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Email: hrec-enquiries@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

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29 August 2023

Dr I Molefe
Forensic Pathologist
Forensic medicine & Toxicology
Email: itumeleng.molefe@uct.ac.za

Dear Dr Molefe

HREC REF NO: 751/2020: INVESTIGATING BLOOD ALCOHOL CONCENTRATIONS IN VIOLENT DEATH AND ITS RELATIONSHIP TO THE COVID-19 NATIONAL LOCKDOWN IN WESTERN CAPE, SOUTH AFRICA- A CROSS-SECTIONAL RETROSPECTIVE REVIEW-MMED CANDIDATE- DR VARUSHKA BACHAN

RE: DATA SHARING BETWEEN HREC REF NO: 751/2020 AND HREC REF NO: 517/2022 (AND LINKED SUBSTUDY HREC REF 338/2023)

Thank you for your letter to the Faculty of Health Sciences Human Research Ethics Committee dated 28 July 2023.

The HREC has granted approval to give you permission for another retrospective study protocol (hrec ref no 517/2022) to access the dataset generated from your protocol hrec ref 751/2020. We note that the hrec ref no 517/2022 also has a substudy linked (hrec ref no: 338/2023).

Yours sincerely

PROFESSOR MARC BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE