# Monitoring pre-hospital transport of severely injured patients in the Midland Region of New Zealand

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## ABSTRACT

**AIM:** Pre-hospital triage strategies aim to identify the type and extent of patient injuries and ensure that they are transferred to the most appropriate trauma centres. Despite the importance of appropriate pre-hospital transport, there is little evidence base to assist medical staff on optimal destination policy for emergent pre-hospital transport. This paper explores the spatial relationship of patient transfers prior to the implementation of the Midland Pre-Hospital Trauma Destination Matrix in New Zealand, and is a retrospective view of practice against a destination policy that was applied after the study period.

**METHODS:** We use data obtained from the Midland Trauma Registry merged with Global Positioning System (GPS) data from St John and Land Information New Zealand Data Service on major trauma occurring in 2014 and 2015. Using ArcGIS, data were analysed for spatial relationships between factors associated with major trauma events and pre-hospital transportation.

**RESULTS:** In the retrospective analysis of 162 major trauma patients, 107 (66%) were transported to a hospital that matched the destination specified in the Matrix, and 55 (34%) were transported to a non-Matrix designated hospital.

**CONCLUSION:** Approximately one-third of patients were not directly transported to the preferred definitive care hospital subsequently defined in the Midland Pre-Hospital Trauma Destination Matrix. Ongoing monitoring of the pre-hospital transportation system and the implementation of a formal pre-hospital transport policy may improve the efficiency of the Midland Trauma System. Future studies should examine the possible reasons for variations in triage decisions across the Midland Region.


In 2013, injuries accounted for 8% of New Zealand's morbidity and mortality (disability-adjusted life years) and were the second greatest cause of morbidity and mortality among children (10%) and youth (23%).[1] The establishment of trauma systems can improve patient outcomes and increase the cost-effectiveness of services.[2–4] Pre-hospital triage strategies aim to identify patients with serious injury and ensure that as many of these patients as possible are transferred to trauma centres that are capable of treating their injuries.[5] Clear evidence-based protocols for triage are important to meet the goal of trauma systems; "to get the right patient to the right facility at the right time".[6,7] Efficient triage is important since many trauma deaths occur within four hours of the incident[8] and triaging severely injured patients to specialised trauma hospitals is associated with reduced mortality and morbidity.[6] Formal triage criteria may aid paramedics in the decision-making process[9] and increase the proportion of direct admissions to trauma centres.[7] Even so, triage protocols are not always adhered to[10] and triage guidelines can result in both under-triage, where patients with severe trauma are not identified, and the over-triage of patients with minor injuries being taken to trauma centres.[8] Although inter-hospital transfers of trauma patients may be necessary when patients are not transported directly to the optimal facility, a well-organised trauma system may reduce these transfers.[11] The impact of inter-hospital transfers on trauma patient out-

**Table 1:** The Midland Major Trauma Pre-hospital Destination Matrix.[28]

| **District** | **Waikato** | | | | | **Bay of Plenty** | | **Lakes** | | **Taranaki** | | **Tairawhiti** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Incident locality** | **WKO** | **THA** | **TOK** | **TAU** | **TEK** | **TGA** | **WHK** | **ROT** | **TPO** | **TBH** | **HAW** | **GIS** |
| **Condition** | **Destination facility** | | | | | | | | | | | |
| *Life-threatening problem requiring immediate medical intervention* | *Destination for life-threatening problem is the closest medical facility that can provide the immediate medical intervention* | | | | | | | | | | | |
| Manageable airway obstruction | WKO | WKO | WKO | WKO | WKO | TGA | WHK | ROT | ROT | TBH | TBH | GIS |
| Respiratory distress | WKO | THA | WKO | TAU | TEK | TGA | WHK | ROT | TPO | TBH | HAW | GIS |
| Shock | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| Motor score less than or equal to 5 | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | WKO | TBH | TBH | GIS |
| Severe TBI likely to need neurosurgeon Age ≥15 | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | GIS |
| Severe TBI likely to need neurosurgeon Age <15 | WKO | SSH | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| Penetrating trauma to neck or torso | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| Penetrating trauma to a limb + arterial injury | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| Crush injury to neck or torso | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| Flail chest | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| More than one long bone fracture | WKO | WKO | WKO | WKO | WKO | TGA | TGA | ROT | ROT | TBH | TBH | GIS |
| Crushed/mangled/amputated/ pulseless limb | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | TBH | TBH | GIS |
| Clinically obvious pelvic fracture | WKO | WKO | WKO | WKO | WKO | TGA | TGA | WKO | WKO | TBH | TBH | GIS |
| Isolated paraplegia or quadriplegia Age ≥15 | MMH | MMH | MMH | MMH | MMH | MMH | MMH | MMH | MMH | CCH | CCH | MMH |
| Isolated paraplegia or quadriplegia Age <15 | SSH | SSH | SSH | SSH | SSH | SSH | SSH | SSH | SSH | SSH | SSH | SSH |
| Multitrauma with paraplegia or quadriplegia | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | GIS |
| Burns involving airway | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | TBH | TBH | GIS |
| Burns >20% body surface area | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | TBH | WKO | GIS |
| Major facial injury | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | WKO | TBH | WKO | GIS |
| Severe multisystem injuries | WKO | WKO | WKO | WKO | WKO | TGA | TGA | WKO | WKO | TBH | WKO | GIS |

WHK = Whakatane Hospital
TGA = Tauranga Hospital
WKO = Waikato Hospital
ROT = Rotorua Hospital
THA = Thames Hospital
TBH = Taranaki Base Hospital
GIS = Gisborne Hospital
SSH = Starship Hospital
TOK = Tokoroa Hospital
TAU = Taumarunui Hospital
TEK = Te Kuiti Hospital
TPO = Taupo Hospital
HAW = Hawera Hospital
MMH = Middlemore Hospital
CCH = Christchurch Hospital

**A. Direct transfer to the destination listed is recommended if rapid and safe transport is available.**

**B. Criteria for "severe TBI likely to need a neurosurgeon":**

1. Intubated or ventilated
2. Lateralising motor signs or unilateral pupillary dilation
3. Clinically obvious penetrating brain injury

comes is not clear. Some evidence suggests a lower risk of death and improved outcomes for directly transported patients.[12–14] However, other studies suggested no difference in outcomes,[15] with a systematic review and meta-analysis demonstrating no significant differences in outcomes for patients with moderate-to-severe head injury or major trauma who experienced direct transport to specialist centres versus initial stabilisation at non-specialist centres.[16] However, it has been argued that direct transportation can reduce the overall time to definitive care facilities by avoiding delays at secondary facilities before patients are transferred to a major trauma centre.[17] Definitive care facilities are "usually a tertiary hospital that is able to provide leadership and total care for all aspects of the injury".[18]

## Trauma triage in Midland Region

Until recently, the lack of formal trauma systems and trauma triage criteria in New Zealand has been problematic.[19–23] In 2010, Midland Trauma System was established in the Midland Region of New Zealand (Waikato, Bay of Plenty, Lakes, Tairāwhiti and Taranaki District Health Boards (DHBs)) to guide and provide regionally consistent trauma care towards world best practice across the DHBs.[24] The capacity and capabilities of the Midland hospitals are well known: Waikato Hospital is a provisional Level 1 trauma centre that provides definitive trauma care for approximately 42% of all Midland residents.[25] Tauranga, Gisborne, Rotorua and Taranaki are regional base hospitals, while the remaining seven hospitals in the Midland Region are local or community hospitals. Middlemore Hospital (Auckland) and Christchurch Hospital are the designated centres for isolated adult Spinal Cord Injuries (SCI) in the upper North Island, and the lower North Island and entire South Island respectively. Starship Hospital (Auckland) is the national paediatric SCI centre.[26] St John is the emergency ambulance provider in the Midland Region, and it also provides pre-hospital emergency care to 97% of New Zealand.[20] In 2012, The Royal Australasian College of Surgeons, New Zealand Trauma Committee recommended that major trauma patients be transported directly to "a facility identified as having the capability to stabilise or definitively manage severe trauma".[27] However, the Ministry of Health has identified that trauma patients are not always referred directly to definitive care.[25] A nationally consistent pre-hospital destination policy has recently been developed between the New Zealand Major Trauma National Clinical Network (MTNCN) and pre-hospital providers, as well as regional policies to guide ambulance officers.[24] The Midland Pre-hospital Trauma Destination Matrix (the Matrix) is a regional destination policy customised to the known capabilities and capacities of Midland Hospitals.[28]

## Study rationale

The Matrix (Table 1) was developed prior to this study by Midland Trauma System (MTS) through a process of regional consultation with senior clinicians across the Midland Region to provide clear criteria for the transportation of severely injured patients to the most appropriate facility for their injuries.[28] Discriminative diagnoses used in the Matrix were developed in partnership with St John and are consistent with national prehospital triage policy. The Matrix covers 12 localities based on all hospitals within the Midland Region. It has subsequently been endorsed by the MNTCN and St John as the clinical decision-making schema for Midland Region. This study is the first stage of a two-part study that aims to improve our understanding of the pre-hospital transportation of patients within the Midland Region, and provides a snapshot of current pre-hospital transportation practice, while the second stage will monitor the trial implementation of the Matrix as a transport policy.

# Methods

## Study design

A retrospective evaluation of pre-hospital transportation was undertaken for trauma patients that met the pre-hospital diagnostic criteria for inclusion into the Matrix. The study proposal was submitted for review to the New Zealand Health and Disability Ethics Committees and was ruled out of scope for detailed ethics evaluation since all patient information was unidentifiable.

## Study population

Major trauma patients that were injured between 1 January 2014 and 31 December 2015 and who met the criteria for major trauma as defined by the 20 "life-threatening problems requiring immediate medical intervention" included in the Matrix (see Table 1) were the subject of analysis. Data were extracted from the Midland Trauma Registry and each incident was linked to specific Global Positioning System (GPS) coordinates representing the St John 'pick up point'. GPS data were provided by St John. Additional geographical data to support analysis, including Territorial Local Authority regional boundaries and the New Zealand coastline, were sourced from the Land Information New Zealand Data Service (https://data.linz.govt.nz/) and Statistics New Zealand (http://www.stats.govt.nz/).

## Data analysis

Data analysis was performed by creating an algorithm using python code in PyScripter 2.7 to be applied in ArcGIS 10.3.1. Since there are no official catchment areas for each hospital, the locality of incidents was assigned by determining the closest hospital. The ArcGIS *Closest Facility Analysis* tool was used to calculate the distance from the GPS location of each major trauma incident to the nearest hospital along the road network and record the name of this hospital. The Matrix was applied to all major trauma incidents within a hospital locality in the form of a conditional statement algorithm. If patients were suffering from certain conditions, such as severe traumatic brain injury, the appropriate destination was Waikato Hospital in most cases. However, for other conditions such as respiratory distress the local hospital was designated as the most appropriate triage destination. This algorithm was applied to each hospital locality in the Matrix to retrospectively assign Matrix designated destination hospitals for all injuries in the sample. One hundred and ninety-three major trauma incidents were identified that met the study criteria. Data cleaning identified 14 duplicate incidents due to some patients being extracted from the database twice as they had multiple conditions and therefore met more than one Matrix criteria. In these cases, since all other patient information was the same, including date and time of injury, the 'least serious' condition was removed to ensure that each patient was only included once in the analysis, leaving 179 major trauma incidents. The data were then imported into ArcGIS 10.3.1 and the trauma incident GPS points were plotted. The accuracy of the GPS data was verified by comparing the Territorial Local Authority that the GPS point was located within with the Territorial Local Authority that contained the location recorded in the trauma registry. At the Territorial Local Authority level, 42 (23%) of the incidents had GPS locations with uncertain accuracy. Since this may have been partially due to the Modifiable Area Unit Problem, whereby the results of data aggregation are influenced by arbitrary boundaries such as census areas or territorial authorities,[29] a manual review of uncertain GPS locations was performed and St John were contacted with a request to review the GPS data for these points. After this second phase of data verification the error rate was reduced to 9% and the 17 remaining inaccurate data points were removed, leaving 162 major trauma incidents in the final analysis. An attribute query was performed to select incidents where the Matrix designated destination matched the facility that the patient was actually transported to. Incidents that matched were designated as "Matrix" incidents, while those that did not match were designated as "Non-Matrix" incidents. It is important to recognise that these triage decisions were not made within the context of the Matrix.

# Results

One hundred and ninety-three major trauma incidents were identified that met the study criteria. Data cleaning identified 14 duplicate incidents, while geographic verification identified 17 inaccurate data points, leaving 162 major trauma incidents in the final analysis.

Of the 162 major trauma patients included in the study, 107 (66%) were transported to a hospital that matched the destination specified in the Matrix, while 55 (34%) were transported to a non-Matrix designated hospital. Figure 1 shows the location of the hospitals, distribution of major trauma incidents and the rate of Matrix-consistent transportation within each district of the

**Figure 1:** Pre-hospital transport of major trauma patients in the Midland Region by DHB.

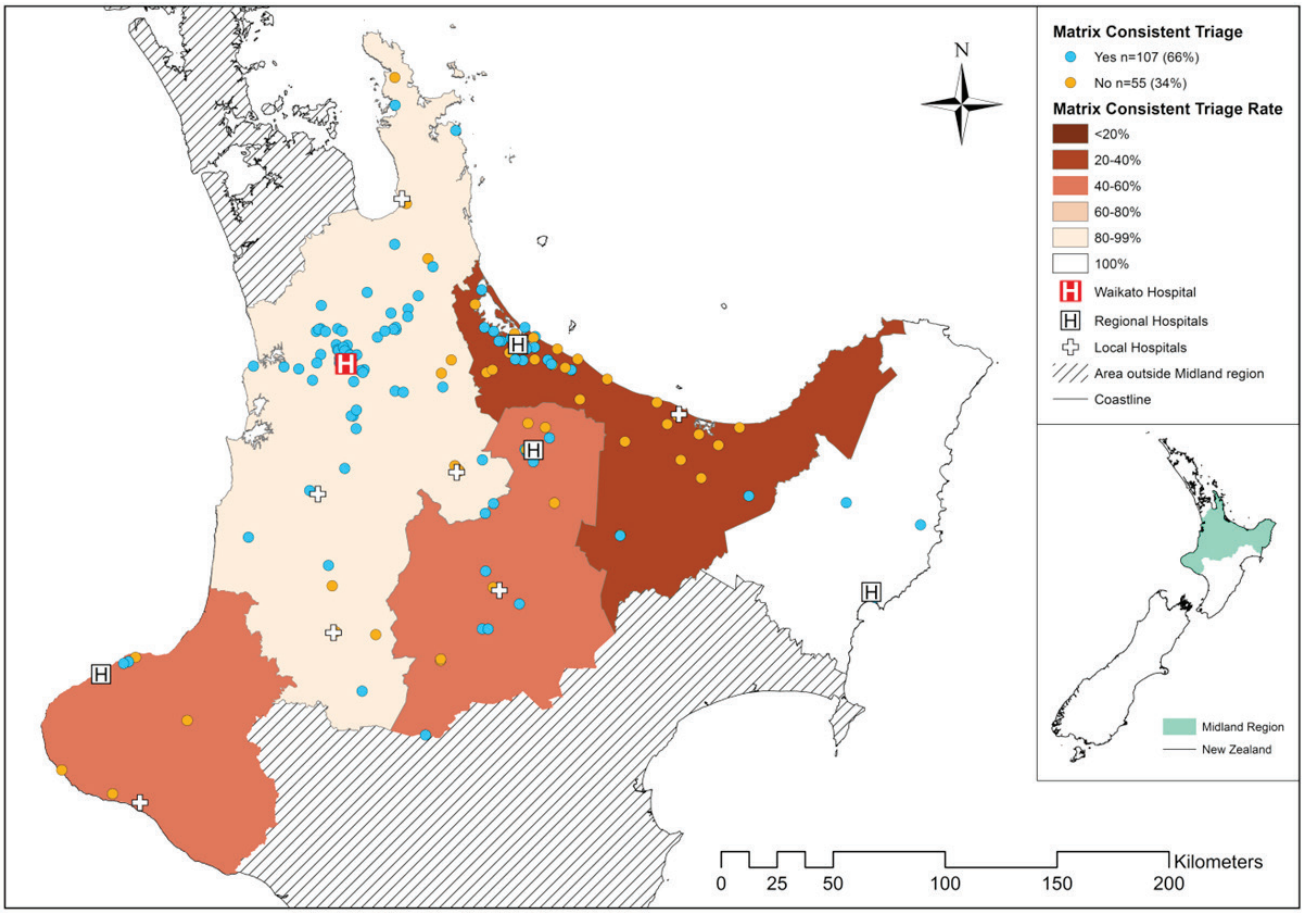


**Table 2:** Differences in triage by receiving hospital.

| Hospital | Matrix destination | Non-Matrix destination |
|---|---|---|
| Whakatāne | 0 (0%) | 9 (100%) |
| Tauranga | 17 (53%) | 15 (47%) |
| Waikato Hospital | 75 (90%) | 8 (10%) |
| Rotorua | 8 (50%) | 8 (50%) |
| Thames | 0 (0%) | 2 (100%) |
| Taranaki | 3 (50%) | 3 (50%) |
| Gisborne | 3 (100%) | 0 (0%) |
| Tokoroa | 0 (0%) | 4 (100%) |
| Taumarunui | 0 (0%) | 3 (100%) |
| Taupō | 1 (33%) | 2 (66%) |
| Middlemore (Auckland) | 0 (0%) | 1 (100%) |
| **Total** | **107 (66%)** | **55 (34%)** |

Midland Region. The blue points on the map represent trauma incidents that were found to have been transported to hospitals in accordance with the Matrix. Orange points represent incidents where pre-hospital transportation was not consistent with the Matrix. The darkest areas of the map represent districts with the lowest rates of Matrix consistent triage (less than 20%) while white areas are districts that had 100% of trauma patients triaged to a Matrix-consistent hospital. The diagonal lines signify areas outside of the Midland Region.

Table 2 displays the number of patients triaged to each hospital and the rate of Matrix consistent triage for each hospital. Tauranga and Whakatāne hospitals had the highest number of pre-hospital transportations that were not consistent with the Matrix, while the highest rates of triage not consistent with the Matrix (100%) were to Whakatāne, Thames, Middlemore, Tokoroa and Taumarunui hospitals. Half of the transportations to Rotorua and Taranaki hospitals were retrospectively deemed to be inconsistent with the Matrix, while the rates of triage not consistent with the Matrix to Tauranga hospital was 47% and two of the three transportations to Taupō hospital did not meet the Matrix criteria. The highest rates of triage that was retrospectively found to be compliant with the Matrix were to Gisborne and Waikato hospitals.

# Discussion

## Key findings

The current study aimed to gain a greater understanding of pre-hospital triage of seriously injured patients in the Midland Region, and makes up the first stage of a two-part study into the use of the pre-hospital triage protocols based on the Midland Matrix. The American College of Surgeons has indicated that acceptable under- and over-triage rates are those that are less than 5% and 35% respectively.[30] Correspondingly, the expectations of MTS for triage accuracy are 0% and 10%. Although this study retrospectively applied the Matrix to major trauma cases that occurred when no formal pre-hospital transport policy existed, the results indicate that 34% of major trauma incidents were transported to a hospital that would not have been designated as the destination able to provide definitive care. This finding suggests that the trauma system in the Midland Region may not be performing optimally. Another key finding is that the rate of triage to non-Matrix facilities varies within the Midland Region. The results indicate that there may be localised factors, such as terrain, distance to major trauma centre or local resource availability, that affect the pre-hospital transportation of major trauma patients within the Midland Region. This finding has implications for both the Midland Trauma System and the overall health system in New Zealand. Health equity is an important part of New Zealand's health strategy and it is recognised that there should be "timely and equitable access for all New Zealanders to a comprehensive range of health and disability services".[31] Figure 1 indicates that within the Midland Region, direct access to the facility best able to provide definitive care is not available equally to all residents, and trauma patients injured in certain DHBs appear to be more likely to be transported to hospitals that are not able to provide definitive care for their particular injuries.

## Importance of this study

To our knowledge this study is the first of its kind to be carried out in the New Zealand context and it provides baseline data on pre-hospital transport in the Midland Trauma System. Continuing to monitor pre-hospital triage and implementing formal pre-hospital transport policies are important steps to ensure that access to definitive care within the trauma system is available to all residents regardless of geographical location. The New Zealand Ministry of Health recognises the importance of a "health system [that] constantly monitors its performance".[31] It has also been argued that well-developed monitoring programmes are essential for ensuring that trauma systems are functioning effectively and efficiently.[17] In particular, field triage guidelines should be assessed for over- and under-triage so that protocols can be improved and local issues identified.[17] The current study raises the case for greater monitoring of pre-hospital transport in New Zealand in order to gain a clearer understanding of how trauma systems are performing and to identify areas for improvement.

# Limitations

This study has several limitations. Primarily, the pre-hospital Matrix criteria were retrospectively applied to the transportation decisions that were made in real time in the field, when there was no official transport destination policy. Therefore, it is important to recognise that the decisions of paramedics were not "correct" or "incorrect" since the Matrix had not been developed or implemented as a pre-hospital transport policy at the time the decisions were made. It is accepted that decisions of paramedics were made in good faith with best available evidence. Furthermore, additional factors that could influence the decisions of paramedics, such as delayed arrival of emergency services, complex extrication of patients, weather or traffic conditions that act as a barrier to rapid transport to a major trauma centre, or resource allocation, were not taken into account by the pre-hospital transport Matrix algorithm. The hypothesis that patients transferred to non-Matrix consistent hospitals may have assumed extra risk or worse outcomes as a result have not been examined in this study. This is likely to be the topic of further studies.

# Conclusions

Retrospective analysis of pre-hospital transport in the Midland Region has revealed that 34% of major trauma patients were not directly transported to the closest hospital capable of providing definitive care for their injuries as defined by the destination Matrix. Ongoing monitoring of the pre-hospital transportation system and the implementation of a formal pre-hospital transport policy may improve the efficiency of the Midland Trauma System. Future studies should examine the possible reasons for variations in triage decisions across the Midland Region.

**Competing interests:**
Nil.

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