MONTANA TRAUMA REGISTRY ANNUAL REPORT 2022

A Summary of 2021 Trauma Data

Public Health IN THE 406

MONTANA
EMS, TRAUMA SYSTEMS & INJURY PREVENTION PROGRAM

Date Published: Dec 20, 2022

EXECUTIVE SUMMARY

We are pleased to present *A Summary of 2021 Trauma Data*, an aggregate and comprehensive report on traumatic injury in Montana, including linked EMS and trauma registry data which allows us to connect prehospital factors to patient outcome. We acknowledge the extraordinary work of those individuals across the state who review trauma case reports and enter this important data into the Montana Trauma Registry (MTR). Without their work, this report would not be possible.

The intent of this report is to build upon last year's baseline for important trauma system measures that can be tracked and improved over time. These measures will assist facilities in their efforts to describe and improve the care for Montanans suffering from injury.

KEY FINDINGS OF THIS REPORT INCLUDE THE FOLLOWING:

- Between the three trauma regions, Eastern has the highest rate of trauma team activation, followed by Western, and then Central.
- Falls continue to be the leading cause of injury among MTR cases, accounting for 57% this year.
- 1 in 3 patients aged 65 and older had a missed trauma team activation based on physiological activation criteria of GCS ≤ 13 and SBP < 110.
- Some patients needing a higher level of care faced ED dwell times of over 20 hours on average, spending an average of 6 days admitted at a smaller facility waiting to be transferred due to lack of bed availability at regional centers as a continued consequence of COVID strain on the health system.
- Almost 40% of teens injured in motor vehicle crashes had alcohol or drugs detected in testing; of those, nearly 70% were unrestrained.
- In 2021, EMSTS initiated training for EMS agencies and hospitals on new TBI treatment, EPIC-MT.

OPPORTUNITIES:

- Interruptions of the EMS records being transferred to the trauma facility impact MTR data quality and need to be proactively monitored and addressed.
- Close monitoring of ED dwell times for trauma patients boarding in the ED can help expose system level problems that need to be addressed in order to improve patient outcomes.
- New field triage guidelines for EMS are being introduced in 2023.It will be important to track whether these correlate to injury severity, a strong predictor of patient outcome.
- Continued collaboration between EMS agencies and facilities to improve care and minimize mortality of TBI patients using the EPIC-MT guidelines.
- Outreach to IHS hospitals (none of which currently submit data) to encourage participation in MTR and associated quality improvement efforts.

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OVERVIEW

The objective of Montana's trauma system is to match trauma patient needs to the appropriate emergency resources available in Montana, or if needed, nearby states. A systems approach requires the cooperation of many stakeholders, and results in increased efficiency and improved trauma patient outcomes. The Montana trauma system's authorizing legislation was passed in 1995 (2-15-2216), which called for the formation of a State Trauma Care Committee (STCC) and three specified trauma regions, based upon patient referral patterns. This legislation allowed adoption of administrative rules regarding trauma center designation, classification, data collection, and triage criteria, and gave legal protection for using trauma data for performance improvement surrounding trauma care.

The MTR is a registry of trauma data established in 1990 to inform the state's trauma care performance improvement activities. All hospitals are required to report data to the trauma registry within 60 days from the end of the quarter. Smaller volume hospitals enter data directly into a web-based registry, while larger facilities enter data into locally hosted registries and upload their files to the MTR. These data are used regularly by the three regional trauma advisory committees (RTACs) and STCC to enhance the quality of patient care by using pre-identified audit filters. Registry data are also used for research, routine surveillance, and to identify opportunities for injury prevention. Selected data are submitted on a regular basis to the National Trauma Data Bank (NTDB) and the Trauma Quality Improvement Program (TQIP).

This annual report includes:

- Description of Montana's trauma facilities and records submitted to MTR during 2021
- Demographics of traumatic injury patients
- Magnitude of traumatic injuries categorized by injury type, cause (mechanism and intent), and injury severity score (ISS)
- Focused analysis of major topics including falls, transportation, firearm, traumatic brain injury (TBI), and work-related injury
- Outcomes of injured patients including case fatality rates and inpatient length of stay
- Performance of prehospital response, trauma team activation, interfacility transfer
- Linkage between EMS and trauma registry records

Limitations

- These data do NOT represent all traumatic injuries in the state. To be included in the MTR, the patient must reach a hospital and meet trauma inclusion criteria (see **APPENDIX 2. Montana Trauma Registry 2021 Inclusion Criteria**). Trauma that results in death at the scene and no transport of the patient is not part of the reported data.
- If a traumatic injury occurs in MT but the patient is treated in an out-of-state facility, the case is not included in MTR data. Border areas are thus under-represented in this report.

MONTANA TRAUMA FACILITIES

Four levels of trauma designation exist currently in Montana.

- Regional Trauma Centers (RTC): Initiate and provide definitive care for all injured patients by serving as the lead trauma facility for a geographical area, which includes outreach to small facilities within the same service area.
- Area Trauma Hospitals (ATH): Provide prompt assessment, resuscitation, surgery, intensive care, and stabilization for most injured patients.
- Community Trauma Facilities (CTF): Provide evaluation, stabilization, diagnostic capabilities, and some surgical coverage for injured patients.
- Trauma Receiving Facilities (TRF): Provide initial evaluation, stabilization, and diagnostic capabilities prior to transfer to definitive care.

Figure 1 shows Montana hospitals designated at each level. See **APPENDIX 1. List of Facilities.**

Figure 1. Count of trauma facilities by designation level

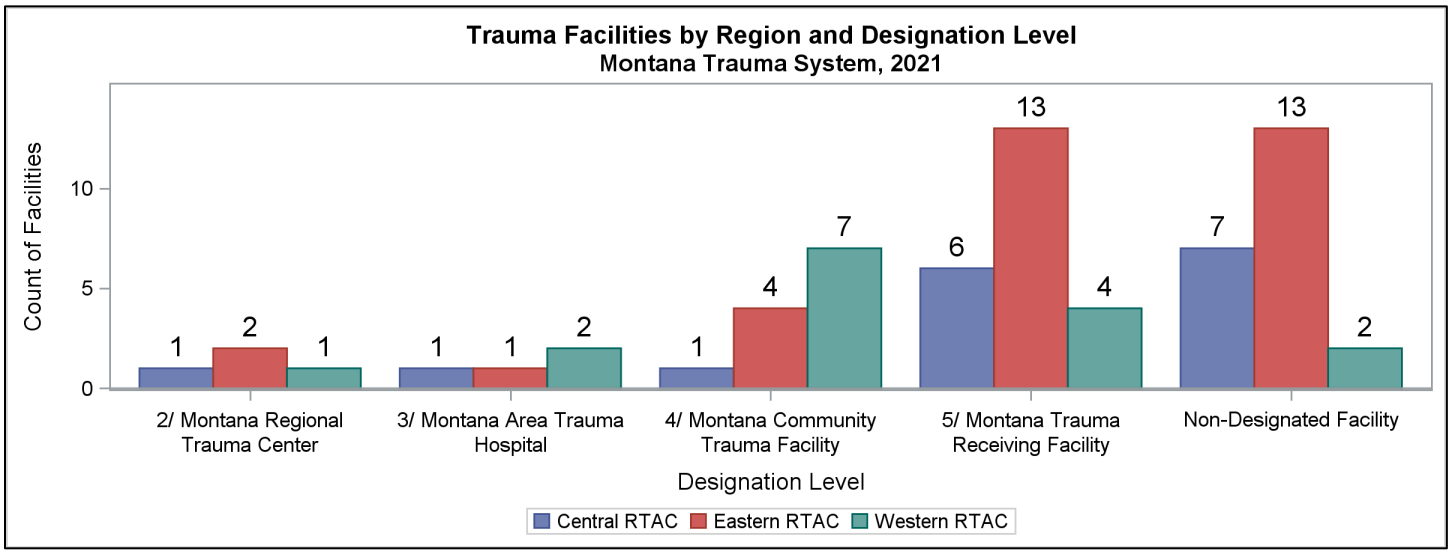
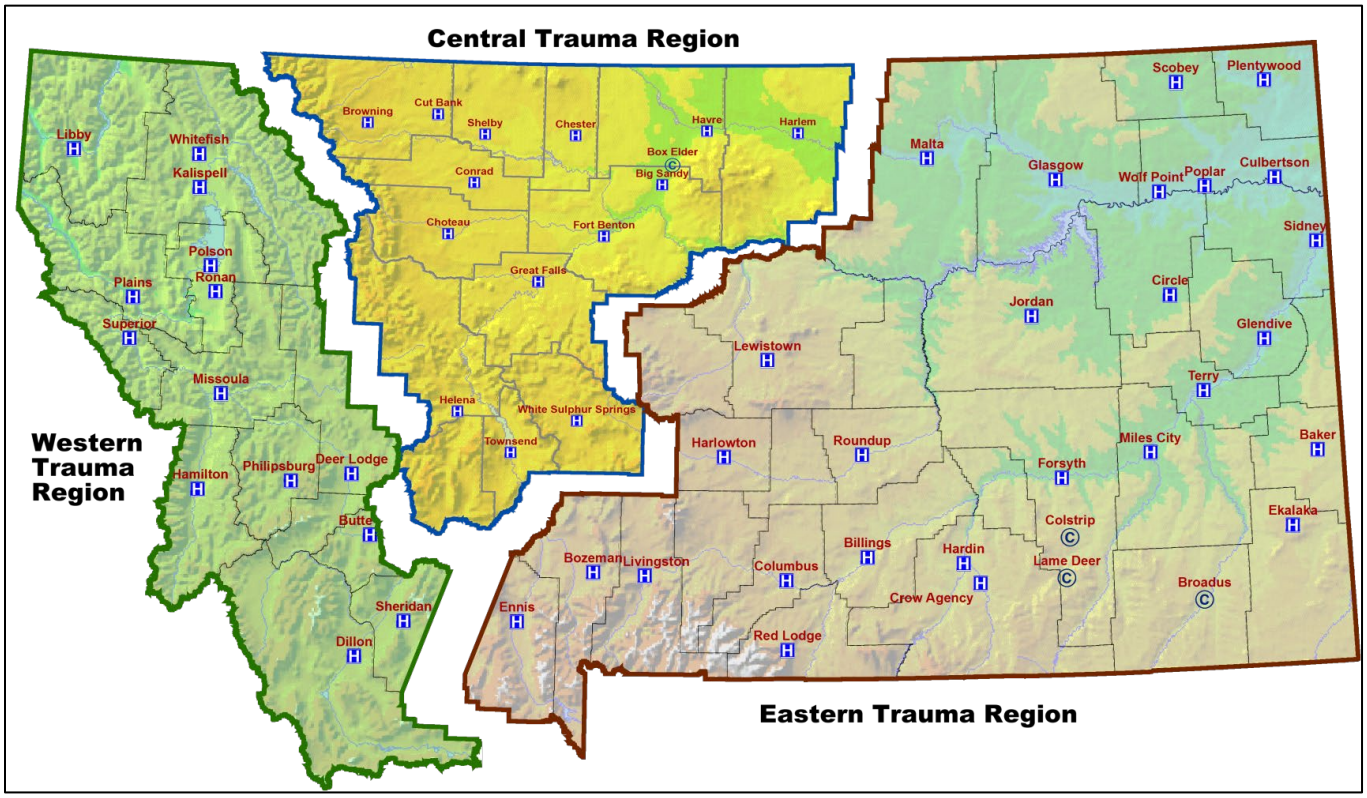


*Figure 2. Map of Montana Trauma Regions**



*Not shown: Big Timber (Eastern), Big Sky (Eastern)

METHODOLOGY

This report includes MTR records for the period 1/1/2021 through 12/31/2021. Data utilized for this report was extracted on 9/8/2022. Any calendar year 2021 data received after this date was not included in the report.

See **APPENDIX 2. Montana Trauma Registry 2021 Inclusion Criteria** and **APPENDIX 3. 2021 MTR analysis dataset inclusion/exclusions flowchart.**

UNITS OF ANALYSIS

Throughout this report, trauma data are presented in two ways:

- **Total trauma records**: All records reported to the trauma registry are counted individually. If a patient was transferred between two or more facilities, that case will be represented twice if both the smaller (sending) and larger (receiving) facility submit a record to the registry. This unit of analysis is useful for describing facility-specific factors and outcome measures such as trauma team activation or ED length of stay. The number of total trauma records reflects total episodes of care in reporting facilities and is greater than the number of patients treated.
- **Unique trauma cases**: Records pertaining to the same patient case are grouped together, by matching trauma records based on patient name, birth date, gender, last 4 digits of SSN, and facility discharge/arrival date. (See **APPENDIX 4. Trauma Dataset De-duplication**). This unit of analysis is useful for describing patient-specific factors and outcomes such as demographics and case fatality rates (where double counting a transfer patient would be misleading). Except if noted otherwise, unique trauma cases are analyzed based on the data from the last facility where the patient received care.

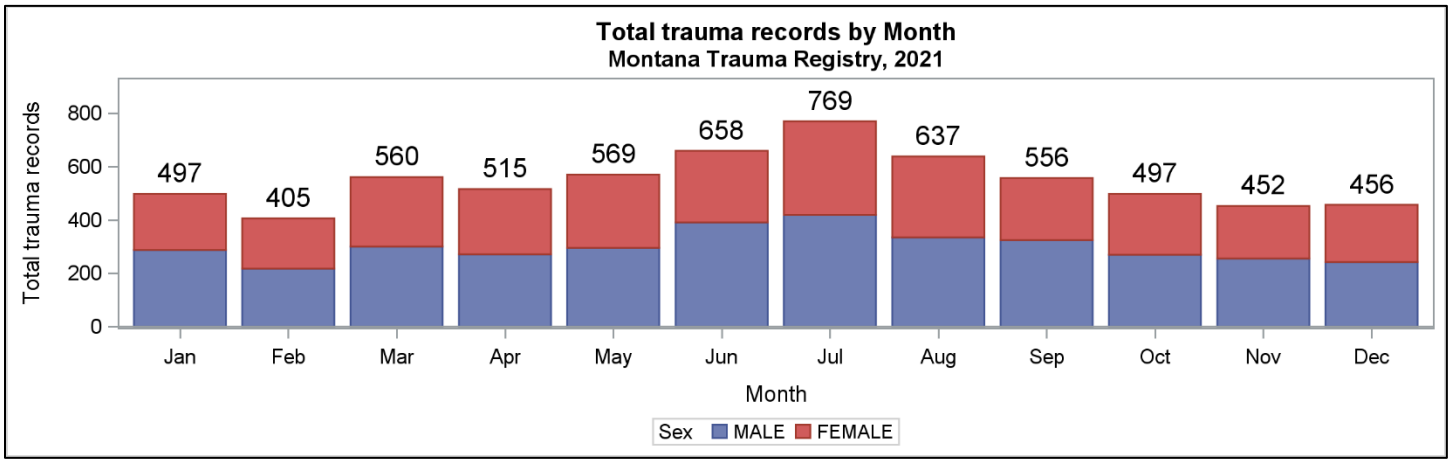
MONTANA TRAUMA REGISTRY RECORDS

There were 6,571 total trauma records comprising 5,854 unique trauma cases included in this report (Table 1). Of 6,571 trauma records, 41% were submitted by facilities in the Eastern trauma region (ERTAC), followed by 39% from the Western trauma region (WRTAC), and 20% from the Central trauma region (CRTAC). An average of 548 records were uploaded into the MTR each month, an increase from 453 in 2020 (Figure 3).

Table 1. Total trauma records and unique trauma cases by RTAC, 2021

RTAC	Total Trauma Records		Unique Trauma Cases	
	N	%	N	%
Central RTAC	1,299	19.8%	1,143	19.5%
Eastern RTAC	2,724	41.5%	2,402	41.0%
Western RTAC	2,548	38.8%	2,309	39.4%
Statewide	**6,571**	**100.0%**	**5,854**	**100.00%**

Figure 3. Total trauma records by month, 2021

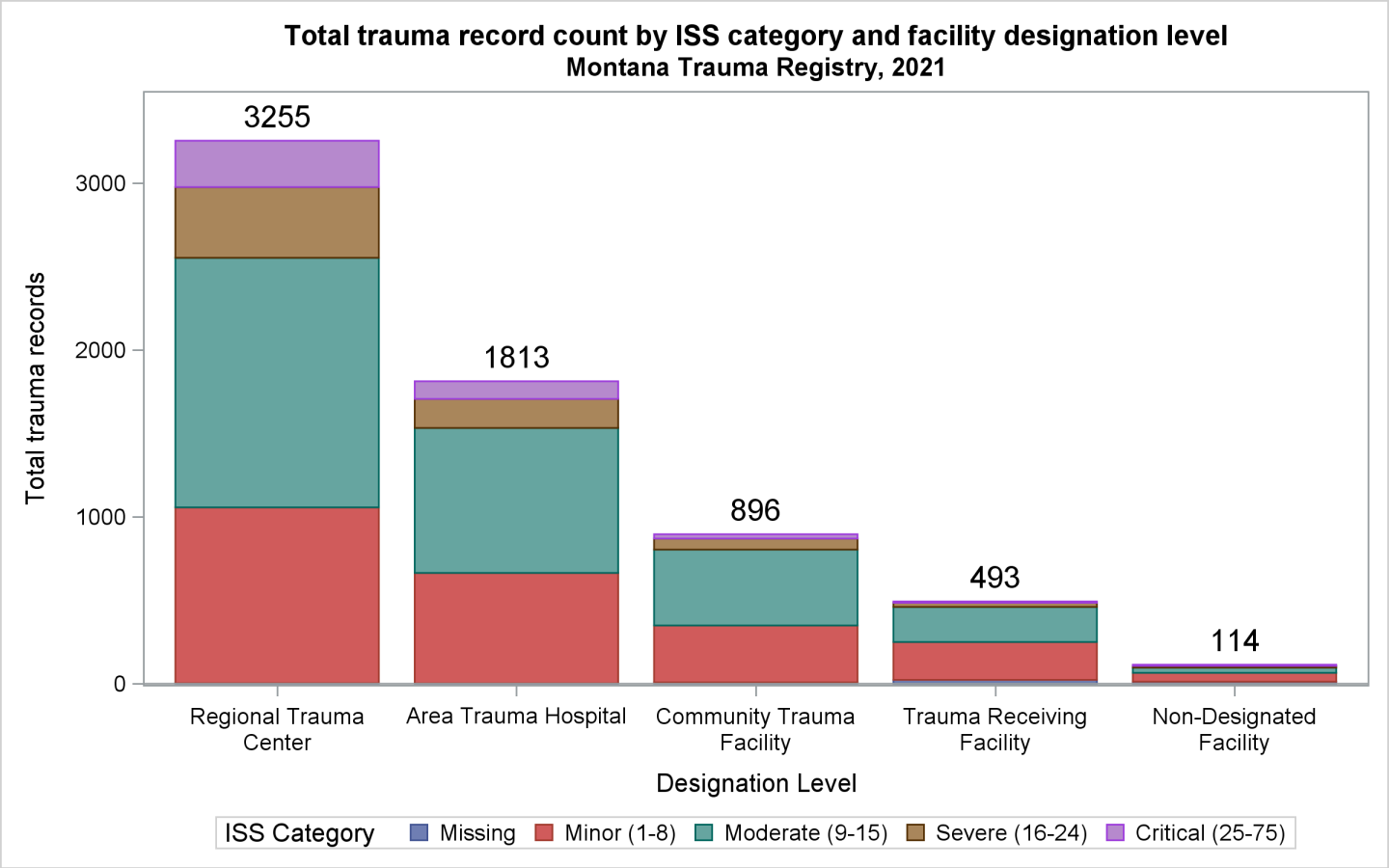


Injury severity score (ISS) is an anatomical scoring system that provides an overall score for patients with multiple injuries. ISS has values from 1-75 with 1-9 as mild, 10-15 as moderate, 16-24 as severe, and over 24 as critical. Montana's RTCs submitted the largest volume of trauma records (N=3,255), 22% of which had an ISS>15. Comparatively, 15% of records from ATCs had an ISS>15, 10% for CTFs, and 7% for TRFs (Table 2).

Table 2. Total trauma records by facility designation level and ISS category, 2021

ISS Category	Designation Level										All	
	RTC		ATH		CTF		TRF		Not Designated			
	N	%	N	%	N	%	N	%	N	%	N	%
Missing	3	0.1%	2	0.1%	8	0.9%	23	4.7%	12	10.5%	48	0.7%
Minor (1-8)	1,054	32.4%	662	36.5%	341	38.1%	227	46.0%	53	46.5%	2,337	35.6%
Moderate (9-15)	1,496	46.0%	869	47.9%	455	50.8%	210	42.6%	31	27.2%	3,061	46.6%
Severe (16-24)	424	13.0%	174	9.6%	66	7.4%	25	5.1%	11	9.6%	700	10.7%
Critical (25-75)	278	8.5%	106	5.8%	26	2.9%	8	1.6%	7	6.1%	425	6.5%
All	**3,255**	**100.0%**	**1,813**	**100.0%**	**896**	**100.0%**	**493**	**100.0%**	**114**	**100.0%**	**6,571**	**100.0%**

Figure 4. Total trauma record count by ISS Category and Facility Designation Level, 2021



MODE OF ARRIVAL

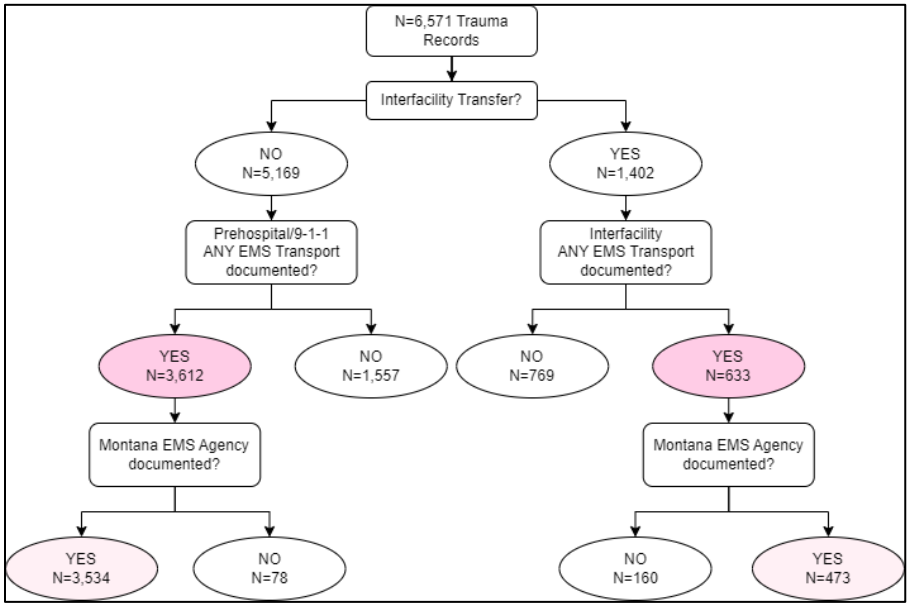
Of 6,571 total trauma records, 79% (N=5,169) were initial arrivals while 21% (N=1,402) arrived as interfacility transfers. Most initial arrivals came by ground ambulance (66%, N=3,402), and 29% (N=1,522) arrived by private vehicle. Among interfacility transfers, 20% (N=284) arrived by ground ambulance, 13% (N=186) by helicopter, and 11% (N=159) by fixed wing. Over 50% of interfacility transfers were missing mode of arrival data (**Table 3**), compared to 2020 when 20% were missing data. The missing data on transport mode may be due to an EMS facility list update that interrupted transfer of records from the EMS agency to the hospitals for a period of time.

Table 3. Total trauma record count by mode of arrival to facility, 2021

Mode of arrival	Initial Arrivals		Interfacility Transfer Arrivals	
	N	Column %	N	Column %
Ground ambulance	3,402	65.8%	284	20.3%
Private vehicle	1,522	29.4%	1	0.1%
Helicopter	185	3.6%	186	13.3%
Ambulance & helicopter	23	0.4%		0.0%
Fixed wing	1	0.0%	159	11.3%
Ambulance & fixed wing		0.0%	4	0.3%
Police/law enforcement	14	0.3%	14	1.0%
Other	5	0.1%		0.0%
Missing	17	0.3%	754	53.8%
All	**5,169**	**100.0%**	**1,402**	**100.0%**

In addition to arrival mode, MTR allows for documentation of the specific EMS agency/agencies that transported the patient. 68% of initial arrivals (N=3,534) and 34% of interfacility transports (N=473) specified a Montana ground or air EMS agency as the transporting agency (**Figure 5**, **Table 4**), leading to a conservative estimate that 4,007 trauma records would be expected to link with an EMS record.

Figure 5. Mode of arrival flowchart, Total trauma records, MTR 2021



TOTAL TRAUMA RECORDS AND LINKAGE TO EMS RECORDS

Table 4 shows the number of total trauma records by submitting facility in Column A. Column B and C show the number of MTR records with documentation of EMS transport to the facility (Column B is based on Mode of Arrival and Column C is based on transporting EMS Agency name). If a patient is transported by EMS to a hospital, it is expected that the corresponding EMS trip report would be found in the EMS data registry. Column D shows the number of trauma records that were linked with a record from the EMS registry. The linkage rate of trauma records with EMS records was 106% when using Column B as the denominator (Column E)[1], and 112% using Column C as the denominator[2]. Linkage rates >100% indicate that although some MTR records were missing data on EMS transport, the matching EMS record was still able to be identified and linked (See **APPENDIX 5. Trauma to EMS record linkage** for details of linking methods).

Table 4. Total trauma record count and linkage to EMS records by reporting facility, 2021

Facility	RTAC	(A) Total Trauma Records	(B) Transported to facility by any EMS	(C) Transported to facility by MT EMS	(D) Linked with EMS record	(E) Linkage rate
		N	N	N	N	
St. Vincent's Healthcare, Billings	ERTAC	902	643	571	622	97%
Billings Clinic, Billings	ERTAC	900	534	432	599	112%
Providence St. Patrick Hospital, Missoula	WRTAC	807	567	556	616	109%
Kalispell Regional Medical Center, Kalispell	WRTAC	695	461	456	488	106%
Benefis Healthcare, Great Falls	CRTAC	646	287	286	498	174%
St. Peter's Hospital, Helena	CRTAC	446	302	293	311	103%
Bozeman Health, Bozeman	ERTAC	376	239	229	251	105%
St. James Healthcare, Butte	WRTAC	296	196	185	200	102%
Community Medical Center, Missoula	WRTAC	189	116	115	114	98%
North Valley Hospital, Whitefish	WRTAC	129	89	83	71	80%
Marcus Daly Memorial Hospital, Hamilton	WRTAC	114	76	76	73	96%
Northern Montana Hospital, Havre	CRTAC	99	69	69	44	64%
Holy Rosary Health Center, Miles City	ERTAC	81	61	61	55	90%
Big Horn County Hospital, Hardin	ERTAC	69	49	49	46	94%
St. Luke Community Healthcare, Ronan	WRTAC	67	54	54	54	100%
Providence St. Joseph Hospital, Polson	WRTAC	65	47	47	47	100%
Barrett Hospital and Healthcare, Dillon	WRTAC	52	30	30	26	87%
Livingston Healthcare, Livingston	ERTAC	47	30	27	23	77%
Bozeman Health, Big Sky Medical Center	ERTAC	47	31	27	22	71%
Community Hospital of Anaconda, Anaconda	WRTAC	43	28	26	28	100%
Pondera Medical Center, Conrad	CRTAC	34	24	24	23	96%

[1] Any EMS Transport: Transport mode = ground or air ambulance, or any EMS agency documented

[2] MT EMS Transport: Licensed Montana EMS agency documented

Facility	RTAC	(A) Total Trauma Records	(B) Transported to facility by any EMS	(C) Transported to facility by MT EMS	(D) Linked with EMS record	(E) Linkage rate
		N	N	N	N	
Beartooth Billings Clinic, Red Lodge	ERTAC	33	19	19	19	100%
Deer Lodge Medical Center, Deer Lodge	WRTAC	32	19	19	19	100%
Mineral Community Hospital, Superior	WRTAC	31	23	23	23	100%
Stillwater Billings Clinic, Columbus	ERTAC	29	21	21	22	105%
Trinity Hospital, Wolf Point	ERTAC	27	21	21	20	95%
Madison Valley Medical Center, Ennis	ERTAC	26	15	15	15	100%
Clark Fork Valley Hospitals, Plains	WRTAC	25	19	19	18	95%
Roundup Memorial Healthcare, Roundup	ERTAC	22	18	18	17	94%
Pioneer Medical Center, Big Timber	ERTAC	22	15	15	13	87%
Frances Mahon Deaconess, Glasgow	ERTAC	19	11	11	11	100%
Northern Rockies Medical Center, Cut Bank	CRTAC	19	16	16	15	94%
Central Montana Medical Center, Lewistown	ERTAC	18	10	9	9	90%
Sidney Health Center, Sidney	ERTAC	18	11	11	11	100%
Wheatland Memorial Hospital, Harlowton	ERTAC	17	9	9	2	22%
Benefis Teton Medical Center, Chouteau	CRTAC	14	9	9	9	100%
Mountainview Medical Center, White Sulphur	CRTAC	13	7	7	7	100%
Marias Medical Center, Shelby	CRTAC	13	10	10	9	90%
Phillips County Medical Center, Malta	ERTAC	12	9	9	9	100%
Northeast Montana Health Services, Poplar	ERTAC	12	7	7	7	100%
Daniels Memorial Hospital, Scobey	ERTAC	11	6	6	6	100%
Great Falls Clinic, Great Falls	CRTAC	11	3	3	3	100%
Sheridan Memorial Hospital, Plentywood	ERTAC	10	8	8	7	88%
Rosebud Healthcare, Forsyth	ERTAC	6	6	6	6	100%
Glendive Medical Center, Glendive	ERTAC	6	5	5	5	100%
Dahl Memorial Healthcare, Ekalaka	ERTAC	6	3	3	3	100%
McCone County Health Center, Circle	ERTAC	5	3	3	3	100%
Ruby Valley Hospital, Sheridan	WRTAC	3	3	3	3	100%
Roosevelt Memorial Hospital, Culbertson	ERTAC	3	3	3	3	100%
Big Sandy Medical Center, Big Sandy	CRTAC	3	2	2	0	0%
Liberty County Hospital, Chester	CRTAC	1	1	1	1	100%
All		**6,571**	**4,245**	**4,007**	**4,506**	106%

TRAUMA TEAM ACTIVATION

Trauma team activation (TTA) refers to the activation of a hospital's trauma team based on the injured patient's mechanism of injury, physiologic criteria, anatomic criteria, or special considerations. Individual hospitals have their own predefined activation criteria, and hospital staff may rely on a report from EMS or the presenting symptoms of a patient arriving by personal vehicle to trigger trauma team activation. Some trauma centers have a single level of trauma activation while others may have multiple tiers, usually two or three. All levels are based specifically on the hospital resources available to the trauma patient and the patient's physiological status. Physiologic activation criteria are met if any two of the following are true:

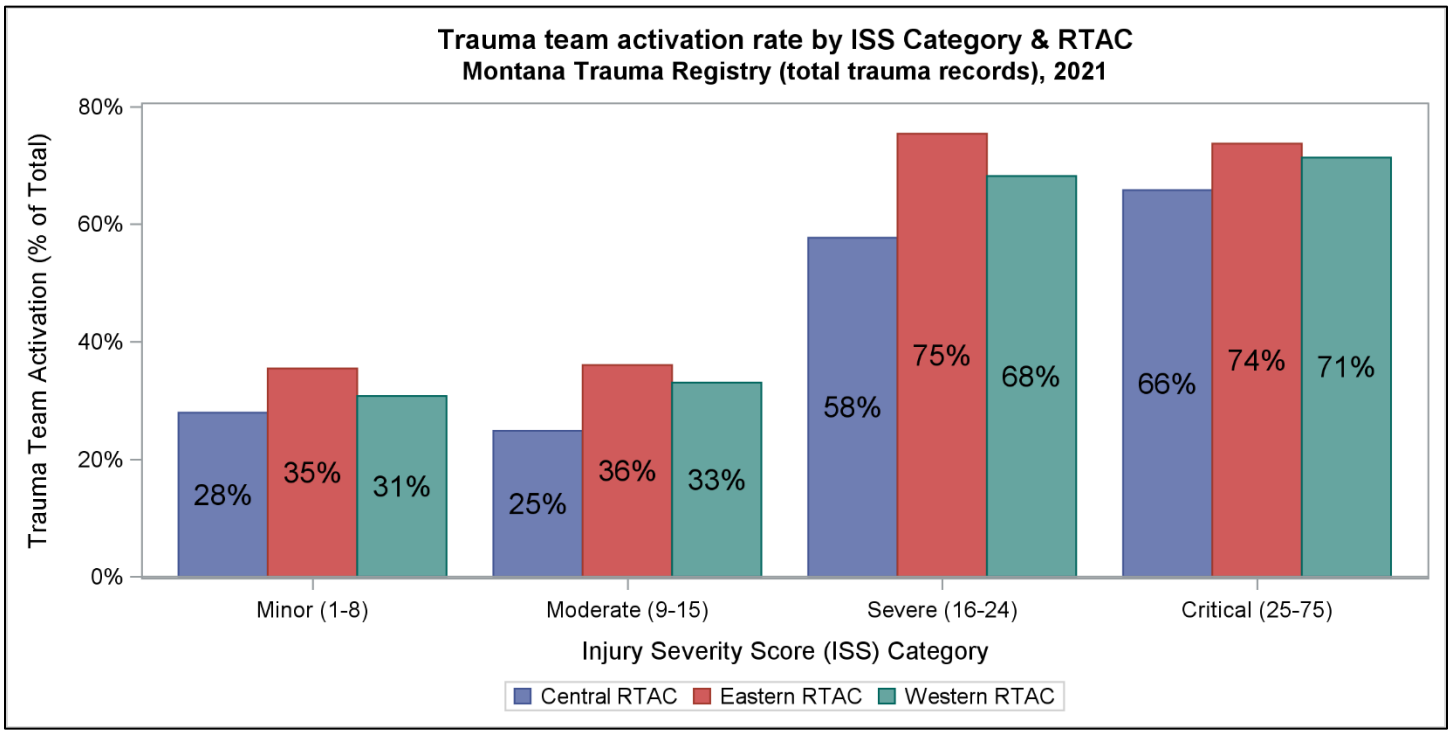
- Any Systolic Blood Pressure (SBP) <90 mmHg
- Any Glasgow Coma Score (GCS) ≤13
- Any respiration assistance=Yes
- Any abnormal Respiratory Rate (RR) (<20 for infants ≤1 year of age, <10 or >29 for all other ages)
- Any abnormal Heart Rate (HR) (<60 or >130 for infants <=1 year of age, <80 or >120 for children 1-8 years of age)

Statewide, the TTA rate was 39% (N=2,563) in 2021, compared with 45% in 2020. TTA is expected to occur more frequently among severely injured patients (ISS>15). **Table 5** and **Figure 6** show the TTA rate within ISS category. CRTAC facilities activated on 61% of severely injured patients, ERTAC facilities activated 75%, and WRTAC facilities activated 69%. All rates were calculated from total trauma records.

Table 5. TTA Rate by ISS Category and RTAC, Total trauma records, MTR 2021

RTAC	ISS <=15		ISS >15		Missing ISS		All Records	
	TTA (N)	TTA Rate (%)	TTA (N)	TTA Rate (%)	TTA (N)	TTA Rate (%)	TTA (N)	TTA Rate (%)
Central RTAC	284	26.3%	125	60.7%	1	8.3%	410	31.6%
Eastern RTAC	778	35.8%	390	74.7%	14	53.8%	1,182	43.4%
Western RTAC	688	32.1%	275	69.3%	8	80.0%	971	38.1%
Statewide	**1,750**	**32.4%**	**790**	**70.2%**	**23**	**47.9%**	**2,563**	**39.0%**

Figure 6. Trauma team activation rate by ISS Category and RTAC, Total trauma records, 2021



When entering data into MTR, trauma registrars may come across cases where the trauma team should have been activated but it was not. Tracking "missed activations" is an important component of quality improvement. Table 6 looks at several types of missed activations. Among patients under 65 years of age who met physiologic activation criteria (N=491), approximately 16% (N=80) did not receive a trauma activation. Patients 65 and older are high risk from traumatic injury, so lower physiologic thresholds for TTA are used in this population. Among patients 65 and older who had SBP <110 mmHg and GCS ≤13,36% (N=22) did not receive a trauma activation (36% in Central, 35% in Western, and 37% in Eastern RTAC). Among patients (all ages) with ISS>15, 30% (N=1,125) did not receive a trauma activation, varying from 25% in Eastern RTAC, to 31% in Western RTAC, and 39% in Central RTAC.

Table 6. Missed Trauma Team Activations by RTAC, Total trauma records, 2021

RTAC	Age <65 & met physiologic activation criteria			ISS >15			Age ≥ 65 with SBP<110 and GCS≤13		
	No TTA*	Total	% Missed	No TTA*	Total	% Missed	No TTA*	Total	% Missed
Central RTAC	18	107	16.8%	81	206	39.3%	4	11	36.4%
Eastern RTAC	30	206	14.6%	132	522	25.3%	7	20	35.0%
Western RTAC	32	178	18.0%	122	397	30.7%	11	30	36.7%
Statewide	**80**	**491**	**16.3%**	**335**	**1,125**	**29.8%**	**22**	**61**	**36.1%**

*No TTA was defined as:
if E_ADMTYPE in ("1-Trauma consult", "3-Non-trauma service") then FLAG_NOTTA=1
if E_ADMTYPE not in ("1-Trauma consult", "3-Non-trauma service", "4-Trauma team Act partial", "5-Trauma team act full") AND INCL_SRC= "5-Retrospective review" then FLAG_NOTTA=1
Else if E_ADMTYPE = "6-Direct Admit" AND INCL_SRC not in ("1-prehospital/EMS", "2-"TTA at this hospital", "5-Retrospective review") AND E_SVC not in (1-TRAUMA, 2-NEUROSURGERY, 3-ORTHOPEDICS, 4-GENERAL SURGERY, 5-THORACIC SURGERY, 6-OTHER SURGICAL SERVICE, 7-BURN) then FLAG_NOTTA=1
Else if E_TTA_DATE=. AND E_TTA_TIME=. then FLAG_NOTTA=1

POST-FACILITY DISPOSITION

Seventy-eight percent (N=5,105) of total trauma records were discharged from inpatient care at the facility. 16% (N=1,071) were transferred to another facility directly from the ED while 2% (N=130) were first admitted and then transferred to another facility. N=197 died while admitted to the facility and N=68 died in the ED (**Figure 7**, **Table 7**).

Figure 7. Disposition at submitting facility, Total trauma records, 2021

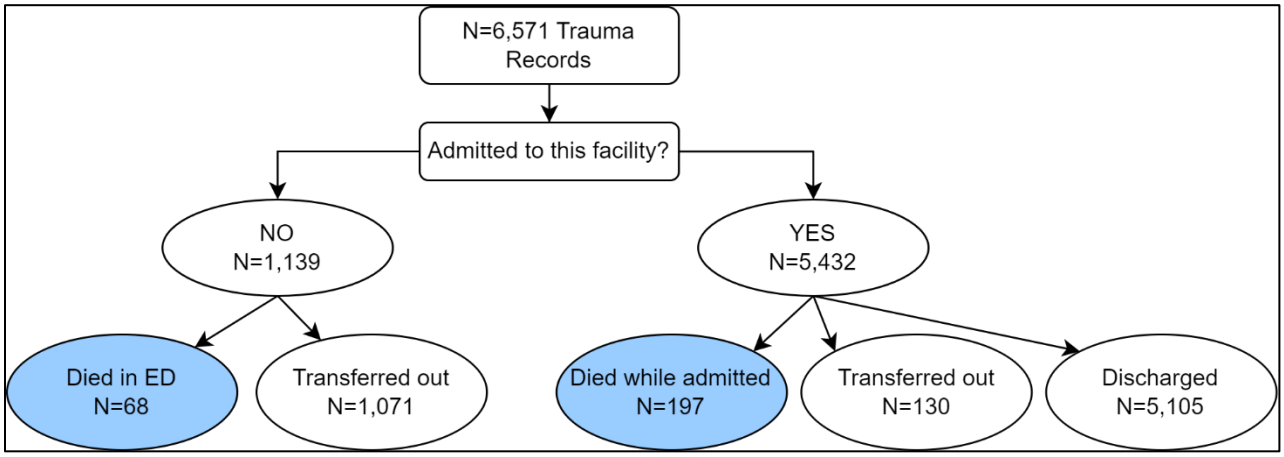


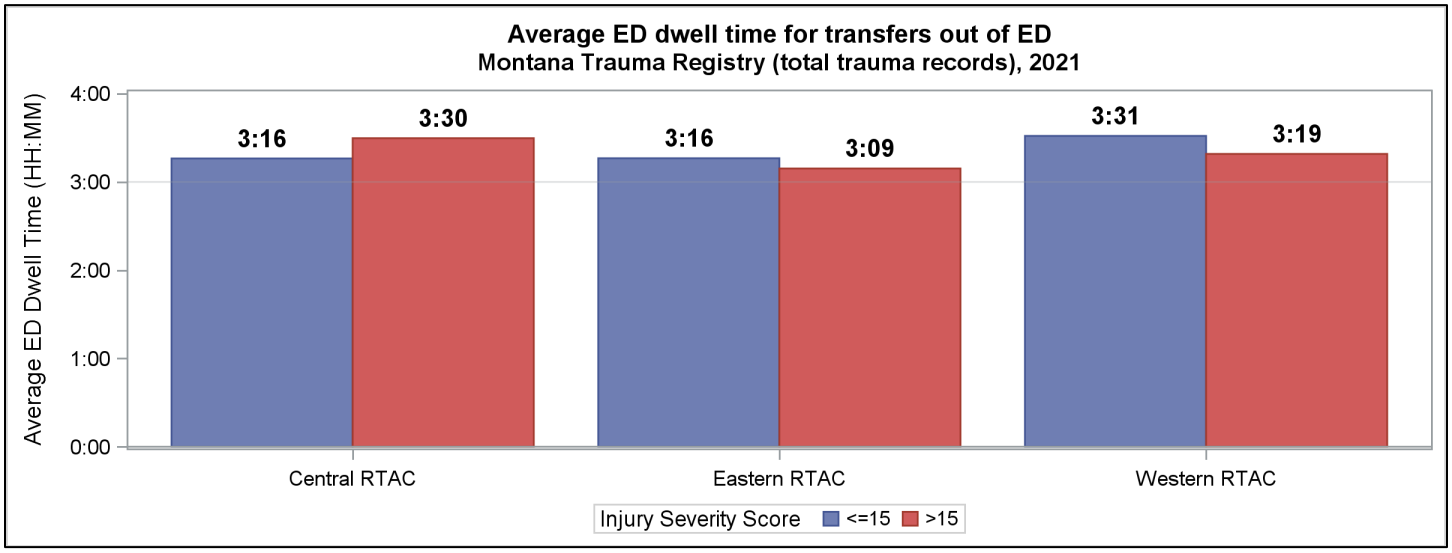
Table 7. Disposition at submitting facility by RTAC, Total trauma records, MTR 2021

Disposition	Central RTAC	Eastern RTAC	Western RTAC	Statewide
Transferred out from ED (to continue acute care)	230	456	385	1,071
Died in ED	8	31	29	68
Admitted to this facility, then transferred out (to continue acute care)	26	43	61	130
Died while admitted to this facility	52	76	69	197
Discharged from inpatient care or left against medical advice	983	2,118	2,004	5,105
All	**1,299**	**2,724**	**2,548**	**6,571**

ED DWELL TIME

Ideally, patients stay in the initial facility's ED less than 3 hours when being transferred to another facility. The average ED dwell time for N=1,071 patients transferred out from the ED was 3 hours 20 minutes (median=2:56). **Figure 8** shows average ED dwell time for these patients by ISS category and RTAC. ED dwell time for ISS <=15 versus ISS >15 were not significantly different[3]. For N=130 patients that were admitted first and then transferred to another facility, the average ED dwell time was 20 hours 43 minutes (median=2:55), and average total time at facility was 6.5 days (median=1.3 days). The extended wait time and ED boarding at sending facilities is related to lack of bed availability due to the increase in overall patient volume since the beginning of the COVID-19 pandemic.

Figure 8. ED dwell time for transfers out of ED, Total trauma records, 2021

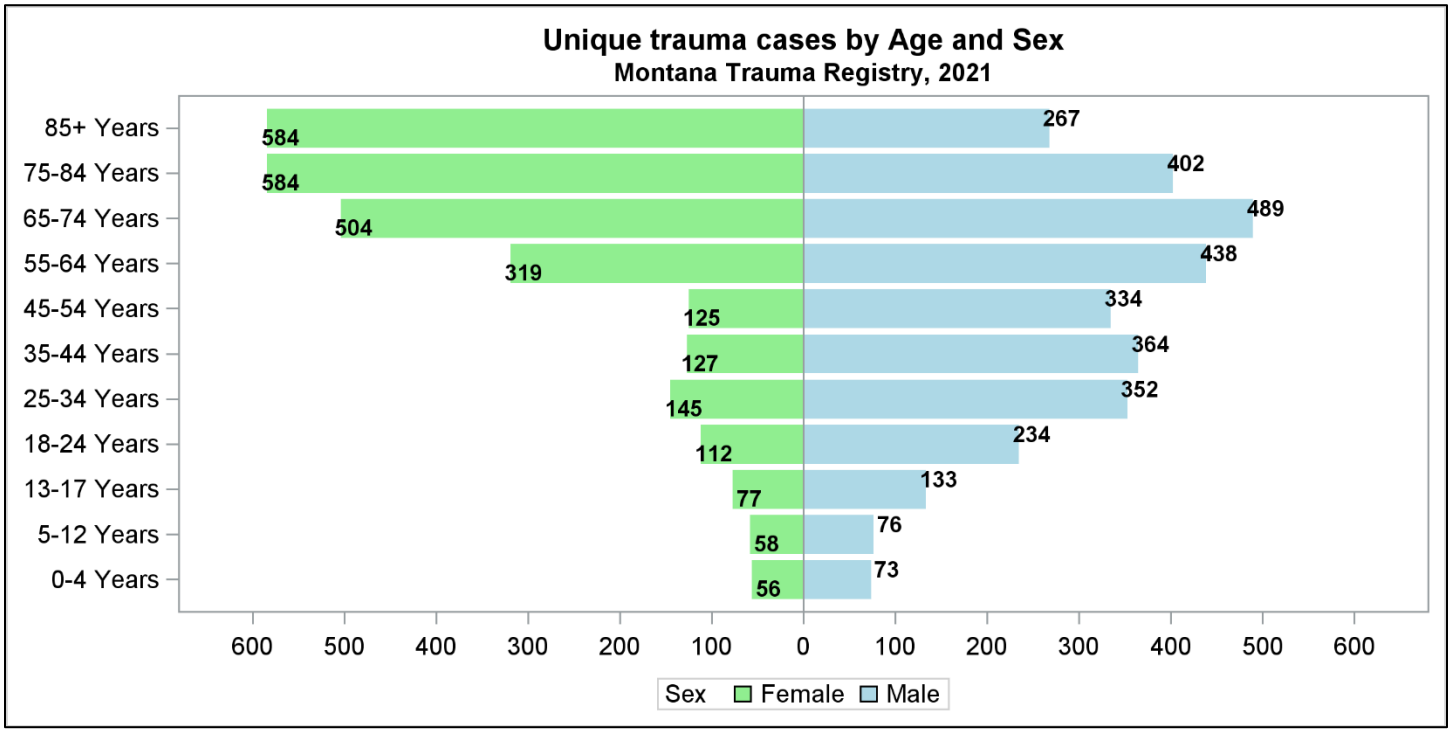


[3] CRTAC p=0.08, ERTAC p=0.50, WRTAC p=0.19

PATIENT DEMOGRAPHICS

Of 5,854 unique trauma cases, 54.0% were male and 46.0% were female. Patients 55 and older made up nearly 60% of cases. Table 8 shows the number and proportion of unique trauma cases by first-listed race.

*Figure 9. Age-sex pyramid, Unique trauma cases, 2021**



*See APPENDIX 6. Montana Population Age-Sex Pyramid

Table 8. Unique trauma cases by first listed race, 2021

First-listed race	N	%
White	5,144	87.9%
American Indian	549	9.4%
Unknown	53	0.9%
Black	44	0.8%
Other	40	0.7%
Asian	15	0.3%
Native Hawaiian or Other Pacific Islander	9	0.2%
All	**5,854**	**100.0%**

OUTCOMES

CASE FATALITY RATE

There were 265 fatal trauma cases during 2021 (Figure 10) for a case fatality rate (CFR) of 4.5% (265/5,854). The CFR was 5.3% among males (N=168) and 3.6% for females (N=97). Figure 11 shows variation in CFR by age and sex, and Figure 12 shows variation by ISS category.

Response time, on-scene time, and transport time[4], of the first EMS 911 responder were not statistically significant predictors of in-hospital mortality (P = 0.73, 0.48, and P = 018, respectively) in a model that adjusted for patient age and sex, while EMS lowest GCS score and higher ISS both predicted increased risk of mortality (P<0.0001 and P<0.0001, respectively).

Figure 10. Deaths by facility designation level, Unique trauma cases, 2021

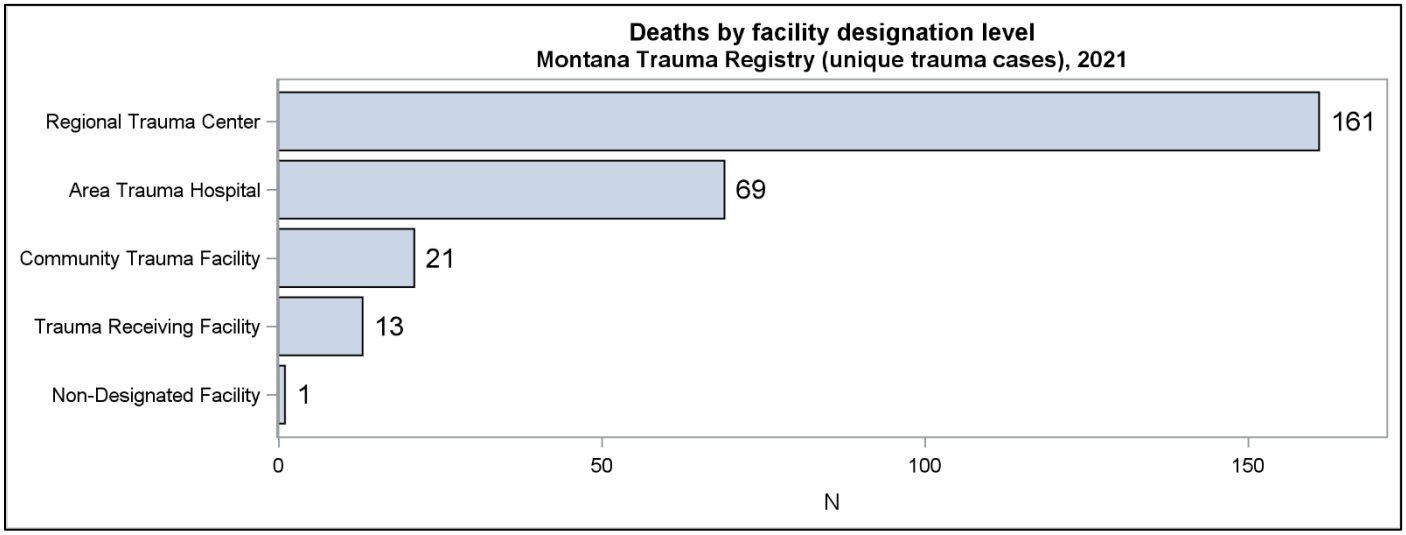
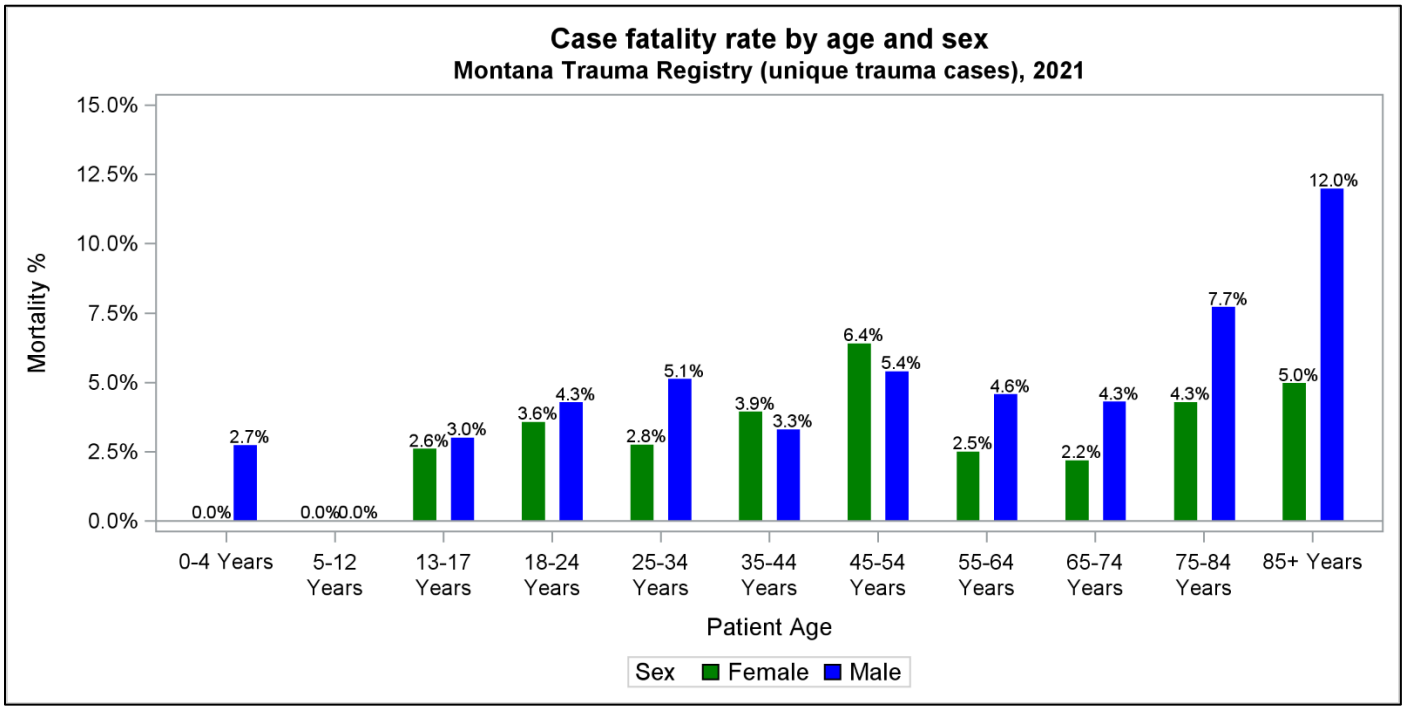
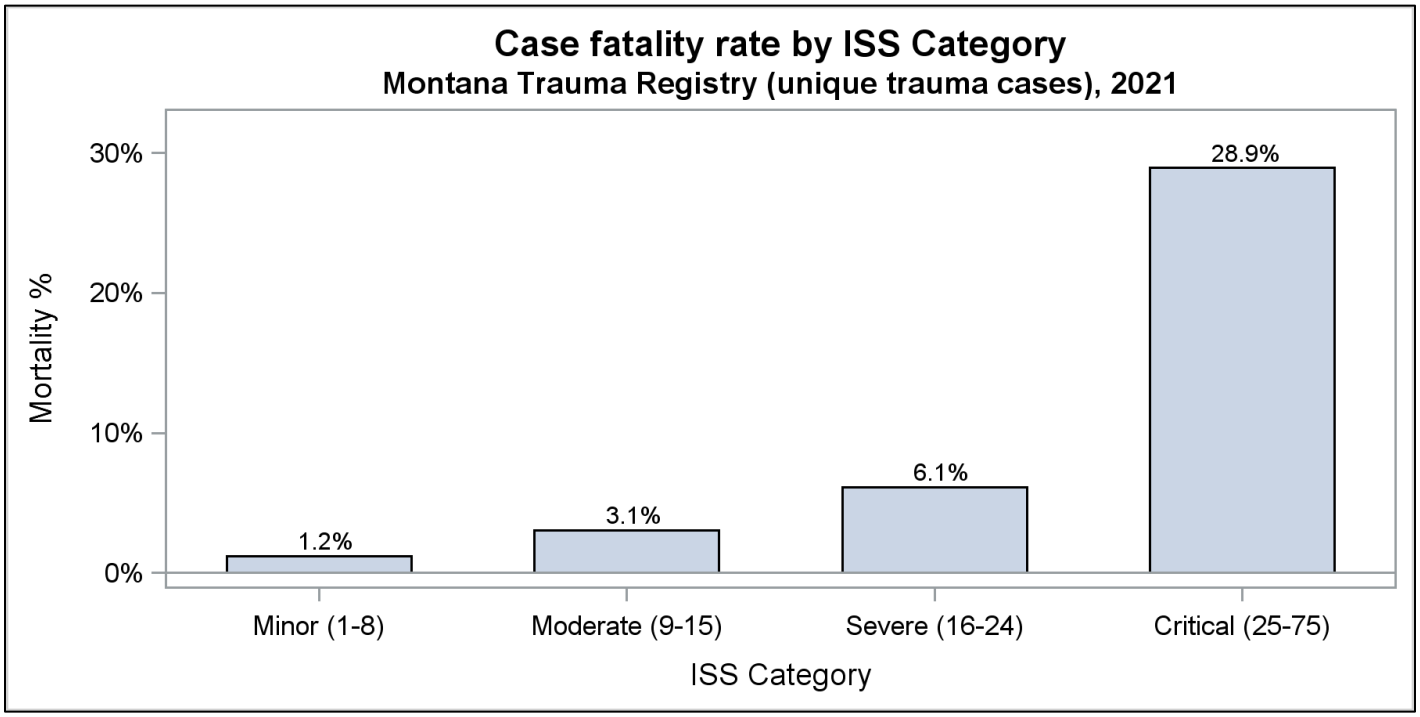


Figure 11. Case fatality rate by age and sex, Unique trauma cases, 2021



[4] Unit notified by dispatch to unit on scene; unit on-scene to unit left scene; unit left scene to unit arrived at the receiving hospital

Figure 12. Case fatality rate by ISS category, Unique trauma cases, 2021

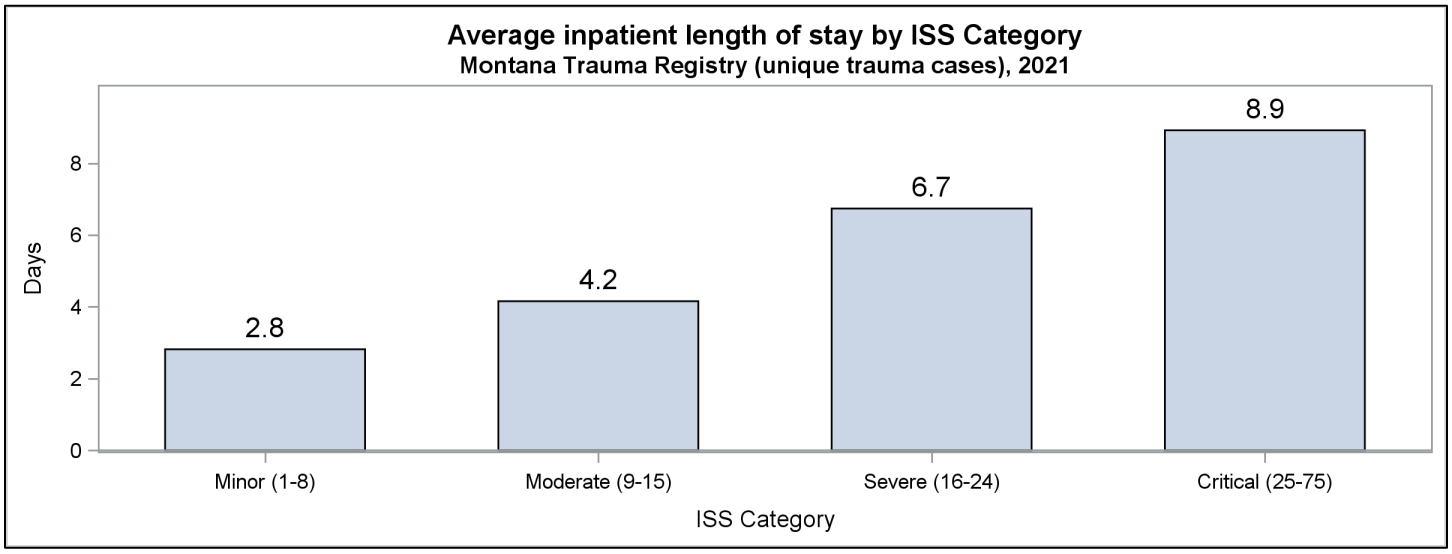


Unintentional falls were the leading cause of in-hospital fatalities (N=130 deaths), followed by unintentional transportation-related injuries (N=78 deaths), and firearm-related injuries (N=30). However, firearm injuries had the highest CFR (23%), while the CFRs for transportation (5%) and falls (4%) were much lower.

INPATIENT LENGTH OF STAY

The average inpatient length of stay (LOS) for unique trauma cases at the final treatment facility was 4.24 days. Higher ISS was correlated with longer length of stay (F=93.59, <0.0001) (**Figure 13**).

Figure 13. Average LOS by ISS category, Unique trauma cases, 2021



INJURY INFORMATION

INJURY TYPE

The majority of injuries (>90%) in the Montana trauma registry are blunt traumas. Penetrating trauma makes up around 5%, and burns comprise around 1%.

Table 9. Total trauma record and unique trauma case count by primary injury type, 2021

Injury Type	Total trauma records		Unique trauma cases*	
	N	%	N	%
Blunt	6,081	92.5%	5,412	92.4%
Penetrating	329	5.0%	292	5.0%
Burn	44	0.7%	41	0.7%
Other and/or Unspecified	93	1.4%	88	1.5%
Not Classified	15	0.2%	13	0.2%
Missing	9	0.1%	8	0.1%
All	**6,571**	**100.0%**	**5,854**	**100.0%**

*Type of injury information taken from primary external cause code of last facility the patient received care at

INJURY CAUSE

Trauma Quality Improvement Program (TQIP) standards were used to categorize injuries by mechanism and intent, based on the primary external cause code (99.9% completeness). Among all ages, unintentional falls were the top injury cause, accounting for 57% of all unique trauma cases, followed by unintentional transportation (27%) (**Table 10**). Among patients aged 0-17, unintentional transportation was the leading injury cause (39%) followed by unintentional falls (32%). Similarly, among those aged 18-64, unintentional transportation accounted for 42% and unintentional falls made up 32%. Among ages 65 and older, unintentional falls were the leading injury (83%).

Table 10. Top 10 causes of injury, Total trauma records and unique trauma cases, 2021

Cause of injury (TQIP)		Total trauma records		Unique trauma cases*	
		N	%	N	%
1	Unintentional- Falls	3,607	54.9%	3,308	56.5%
2	Unintentional- Transportation	1,871	28.5%	1,590	27.2%
3	Unintentional- Struck By/Against	190	2.9%	170	2.9%
4	Assault/Homicide- Struck By/Against	153	2.3%	127	2.2%
5	Unintentional- Natural/Environmental- Other	133	2.0%	105	1.8%
6	Unintentional- Other Specified- Classifiable	98	1.5%	91	1.6%
7	Assault/Homicide- Cut/Pierce	67	1.0%	57	1.0%
8	Unintentional- Cut/Pierce	57	0.9%	54	0.9%
9	Assault/Homicide- Firearm	48	0.7%	42	0.7%
10	Self-harm/Suicide- Firearm	38	0.6%	32	0.5%
	All Top 10	6,262	95.3%	5,576	95.3%
	Other	300	4.6%	270	4.6%
	Missing	9	0.1%	8	0.1%
	Total	**6,571**	**100.0%**	**5,854**	**100.0%**

Table 11. Unique trauma cases by injury mechanism and intent, 2021

Mechanism (TQIP)	Intent (TQIP)					All
	Unintentional	Self-harm/ Suicide	Assault/ Homicide	Other/ Undetermined	Missing	
	N	N	N	N	N	N
Cut/Pierce	54	31	57	6	.	148
Drowning/Submersion	3	.	.	1	.	4
Fall	3,308	6	.	2	.	3,316
Fire/Flame	30	.	1	.	.	31
Hot Object or Substance	10	.	.	.	.	10
Firearm	30	32	42	20	.	124
Machinery	20	.	.	.	.	20
MVT- Occupant	614	2	.	.	.	616
MVT- Motorcyclist	167	.	.	.	.	167
MVT- Pedal Cyclist	8	.	.	.	.	8
MVT- Pedestrian	48	.	3	.	.	51
MVT- Other	233	3	.	.	.	236
MVT- Unspecified	11	.	.	.	.	11
Pedal Cyclist- Other	99	.	.	.	.	99
Pedestrian- Other	32	.	.	.	.	32
Other Transport	378	.	.	.	.	378
Natural/Environmental- Other	105	.	.	.	.	105
Overexertion	17	.	.	.	.	17
Struck By/Against	170	1	127	3	.	301
Suffocation/Asphyxiation	.	5	.	.	.	5
Other Specified- Classifiable	91	.	6	2	.	99
Other Specified, Not Elsewhere Classifiable	13	7	.	9	.	29
Natural/Environmental- Bites and Stings	21	.	.	.	.	21
Unspecified	.	.	17	1	.	18
Missing	.	.	.	.	8	8
All	**5,462**	**87**	**253**	**44**	**8**	**5,854**

INJURY SEVERITY

Seventeen percent (N=984) of unique trauma cases had ISS >15 indicating severe or critical injury (**Table 12**).

Table 12. Injury severity score, Unique trauma cases, 2021

ISS category	N	%
Minor (1-8)	2,091	35.7%
Moderate (9-15)	2,750	47.0%
Severe (16-24)	604	10.3%
Critical (25-75)	380	6.5%
Missing ISS	29	0.5%
All	**5,854**	**100**

Certain causes of injury (where N>5) resulted in consistently more severe injuries, including self-harm, intentional firearm injuries, and motorcyclist injuries (**Table 13**).

Table 13. Cause of injury with average ISS >15, Unique trauma cases, 2021

Cause of injury (TQIP)	Total N	Mean ISS
Other/Undetermined-Firearm	20	20.0
Unintentional-MVT- Motorcyclist	167	16.5
Self-harm/Suicide-Firearm	31	16.1
Self-harm/Suicide-Other Specified- Not Elsewhere Classifiable	7	15.1

There were N=3,292 unique trauma cases linked with an EMS 911 response record, and 19% of these (N=570) had an ISS >15. Using the linked dataset, we found that several EMS field triage criteria correlated with a greater probability of ISS >15 (major trauma) in multivariate analysis ($p<0.05$) adjusted for patient age and sex. This is important because it demonstrates that utilizing the CDC field triage criteria can assist EMS providers and hospital staff in accurately identifying severely injured patients.

Table 14. EMS-documented field triage criteria associated with increased probability of major trauma (adjusted model), Unique trauma cases linked with EMS, 2021

Code	Field Triage Criteria	Total N	N with ISS >15	Odds Ratio	P-Value
2903005	Chest wall instability or deformity (e.g., flail chest)	32	23	7.12	<0.001
2903007	Glasgow Coma Score <= 13	166	85	2.25	<0.001
2903011	Paralysis	10	8	17.26	<0.001
2903015	All penetrating injuries to head, neck, torso, and extremities proximal to elbow or knee	65	30	1.75	0.049
2903017	Respiratory Rate <10 or >29 breaths per minute (<20 in infants aged <1 year) or need for ventilatory support	53	38	3.167	0.001
2903019	Systolic Blood Pressure <90 mmHg	47	27	2.05	0.043
2904011	Crash Intrusion, including roof: > 12 in. occupant site; > 18 in. any site	89	47	2.18	0.003

WORK-RELATED INJURY

Work-related trauma is defined as an injury that occurs during paid employment. There were 221 work-related trauma cases (3.8% of all unique trauma cases), including 6 fatalities. **Table 15** shows the industry associated with the patient's work environment for work-related unique trauma cases. Construction is the industry category with the greatest number of cases (29%), followed by agriculture/forestry/fishing (19%) (**Table 15**). Falls were the most common cause of injury, accounting for 41% of work-related trauma cases and 67% of work-related fatalities (**Table 16**).

Table 15. Work-related unique trauma cases by industry, 2021

Occupational Industry	Unique Trauma Cases		Fatalities	
	N	%	N	%
Construction	64	29.0%	2	33.3%
Agriculture, Forestry, Fishing	41	18.6%	3	50.0%
Other Services	31	14.0%	0	0.0%
Transportation and Public Utilities	18	8.1%	0	0.0%
Unknown	16	7.2%	0	0.0%
Retail Trade	15	6.8%	1	16.7%
Natural Resources and Mining	10	4.5%	0	0.0%
Leisure and Hospitality	9	4.1%	0	0.0%
Professional and Business Services	4	1.8%	0	0.0%
Manufacturing	3	1.4%	0	0.0%
Wholesale Trade	3	1.4%	0	0.0%
Government	3	1.4%	0	0.0%
Education and Health Services	2	0.9%	0	0.0%
Finance, Insurance, and Real Estate	1	0.5%	0	0.0%
Not Applicable	1	0.5%	0	0.0%
All	**221**	**100.0%**	**6**	**100.0%**

Table 16. Work-related unique trauma cases by cause of injury, 2021

Cause of injury	N	%
Unintentional-Fall	91	41.2%
Unintentional-Transportation	46	20.8%
Unintentional-Other Specified- Classifiable	24	10.9%
Unintentional-Struck By/Against	24	10.9%
Unintentional-Natural/Environmental- Other	10	4.5%
Unintentional-Machinery	8	3.6%
Unintentional-Cut/Pierce	5	2.3%
Unintentional-Hot Object or Substance	4	1.8%
Unintentional-Fire/Flame	3	1.4%
Assault/Homicide-Cut/Pierce	3	1.4%
Other	3	1.4%
All	**221**	**100.0%**

UNINTENTIONAL TRANSPORTATION-RELATED TRAUMA[5]

In 2021, MTR captured 1,215 unique trauma cases involving a motor vehicle (MV) occupant unintentional injury, and an additional 389 transportation-related cases including animal riders (N=172), pedal cyclists (N=107), and pedestrians (N=81). There were 78 in-hospital deaths due to unintentional transportation-related injuries for a CFR of 4.9%.

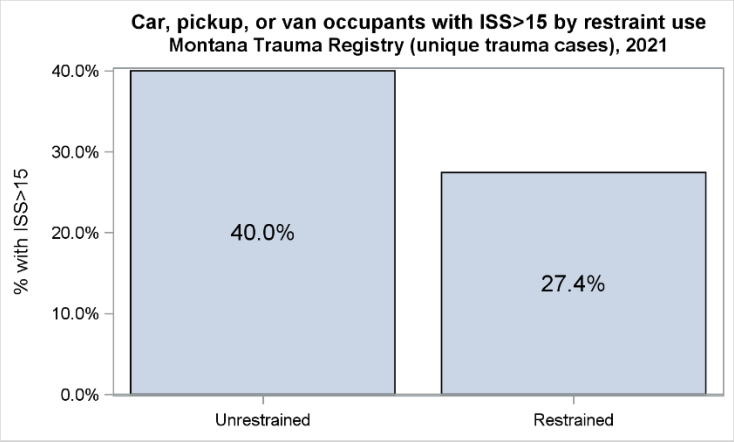
Table 17. Unintentional transportation-related injury by person type, Unique trauma cases, 2021

Mechanism	Motor Vehicle Occupant	Other Person Type	Total N	Average ISS
MV-OCCUPANT (TRAFFIC)	**630**		**630**	**14.49**
Car	487			
Pick-up truck or van	87			
3- or 4-wheeled ATV	39			
Heavy transport vehicle	16			
Unspecified vehicle	11			
Other special all-terrain or off-road motor vehicle	4			
Dirt bike or motocross bike	3			
Bus	2			
Three-wheeled motor vehicle	1			
MOTORCYCLIST (TRAFFIC)	**166**		**166**	**16.46**
MV-OCCUPANT (NONTRAFFIC)	**369**		**369**	**11.10**
3- or 4-wheeled ATV	108			
Car	108			
Motorcycle	76			
Pick-up truck or van	27			
Dirt bike or motocross bike	25			
Heavy transport/agricultural/construction vehicle	18			
Three-wheeled motor vehicle	4			
Railway train	1			
Bus	1			
Unspecified vehicle	1			
OTHER LAND TRANSPORT	**50**	**172**	**222**	**10.77**
Animal Rider		*172*		
Snowmobile	*26*			
Other special all-terrain or off-road motor vehicle	*18*			
Railway train	*2*			
Special construction/industrial vehicle	*2*			
Unspecified Nonmotor Vehicle	*2*			
OTHER TRANSPORT	**0**	**29**	**29**	**13.14**
Water transport		15		
Air transport		11		
Other specified		3		
MV-PEDAL CYCLIST (TRAFFIC)		**8**	**8**	**13.38**
PEDAL CYCLIST, OTHER		**99**	**99**	**9.38**
MV-PEDESTRIAN (TRAFFIC)		**50**	**50**	**13.20**
PEDESTRIAN, OTHER		**31**	**31**	**13.35**
All	**1,215**	**389**	**1,604**	**12.99**

[5] MTR final facility record's first or second external cause of injury code = ICD-10-CM codes V01-V99

Of 709 car, pick-up truck, or van occupants, 44% were restrained (N=312), 41% were unrestrained (N=290), and 15% (N= 107) had unknown restraint use. Among those with known restraint status, 40% of unrestrained occupants had ISS>15 versus 27% of restrained occupants (X^2= 10.6, p=0.0012) (**Figure 14**).

Figure 14. Percent of car, pick-up truck, or van occupants with ISS>15 by restraint use, 2021

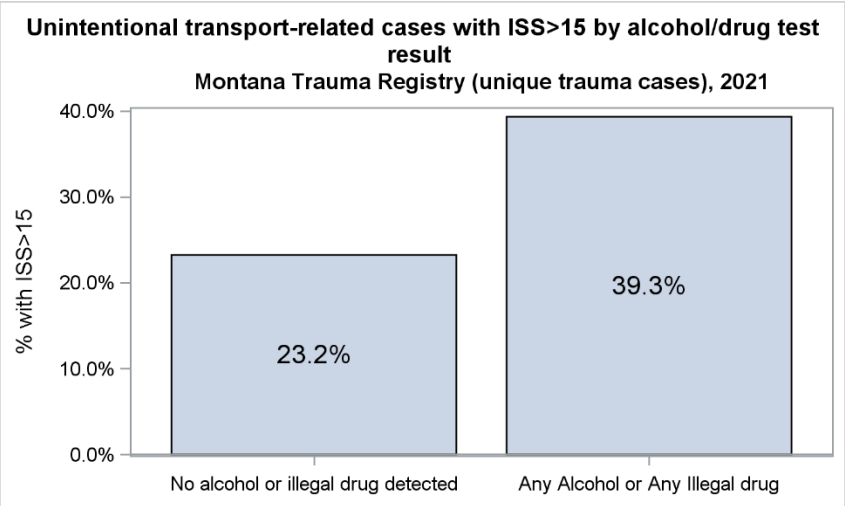


Alcohol (any amount) was detected in 25% (N=403) of unintentional transport-related trauma cases, while levels above the legal limit were detected in 21% (N=330) of cases **(Figure 16)**. 40% (N=642) were negative for alcohol upon testing, and 35% (N=559) of cases were not tested for alcohol. Illegal drugs were detected in 18% (N=287) of cases and prescription drugs in 7% (N=120). 58% (N=935) were not tested for drugs.

35% of cases (N=562) had any alcohol or illegal drugs detected with testing. Cases with alcohol or drugs detected were more likely to have ISS>15 versus those with no alcohol or drugs (39% versus 23% respectively) (X^2= 47.8, p < 0.0001) **(Figure 15)**.

Of the 562 cases with any alcohol or illegal drugs detected, 322 were car, pickup, or van occupants. 25% were restrained, 55% were unrestrained, and 20% had unknown restraint status. Those who were unrestrained were more likely to have severe injuries (44%) than those who were restrained (27%) (X^2= 6.8, p=0.0093).

Figure 15. Percent of unintentional transportation-related unique trauma cases with ISS>15 by alcohol/drug test result, 2021



Cannabis was found in 14% of all cases, and in 26% of cases where alcohol was also detected. Alcohol and cannabis was the most common poly-substance combination, followed by opioids and cannabinoids, then alcohol and opioids (**Figure 16**, **Figure 17**).

Figure 16. Alcohol and drugs detected in transportation-related unique trauma cases, 2021

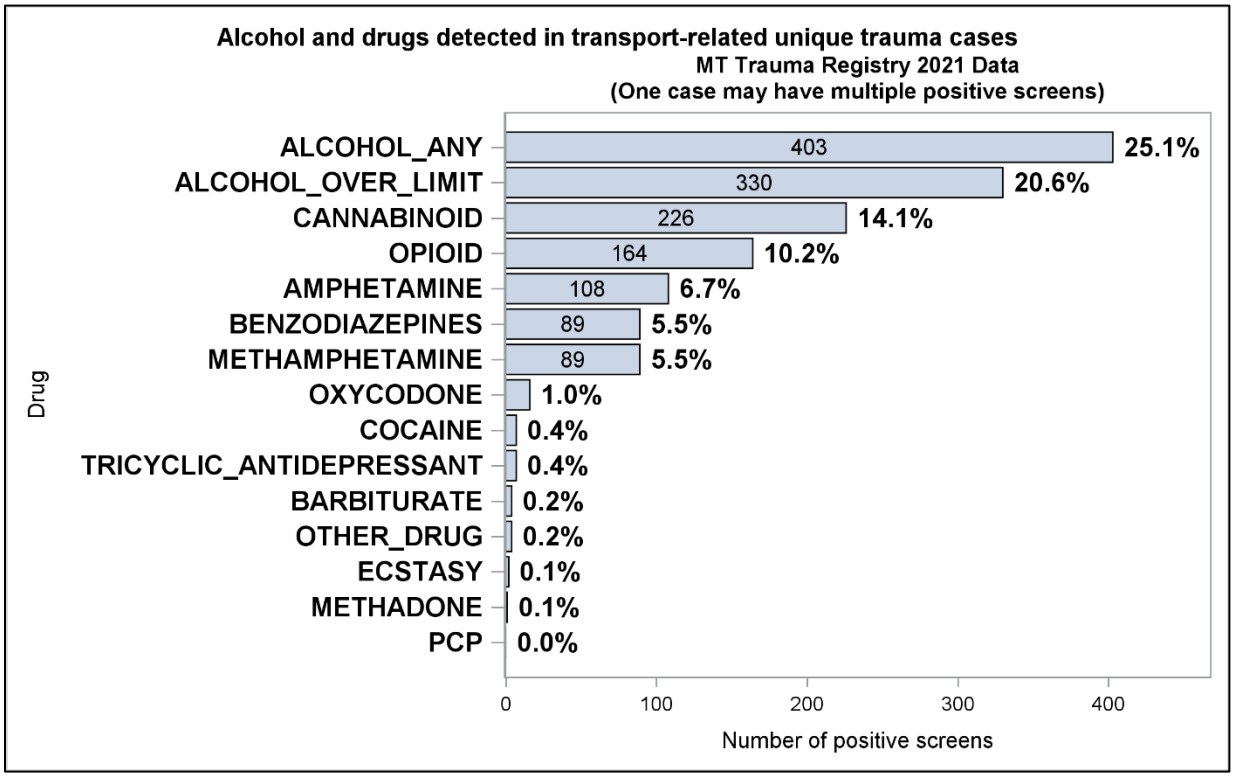
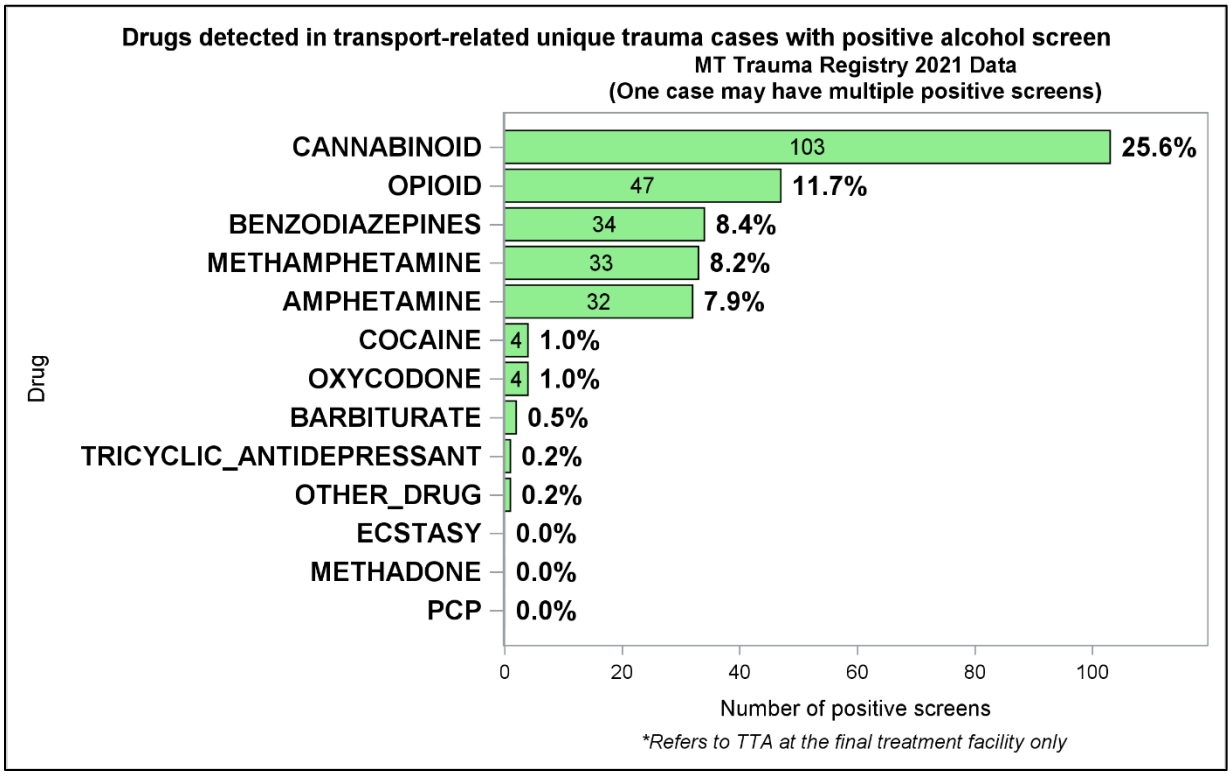


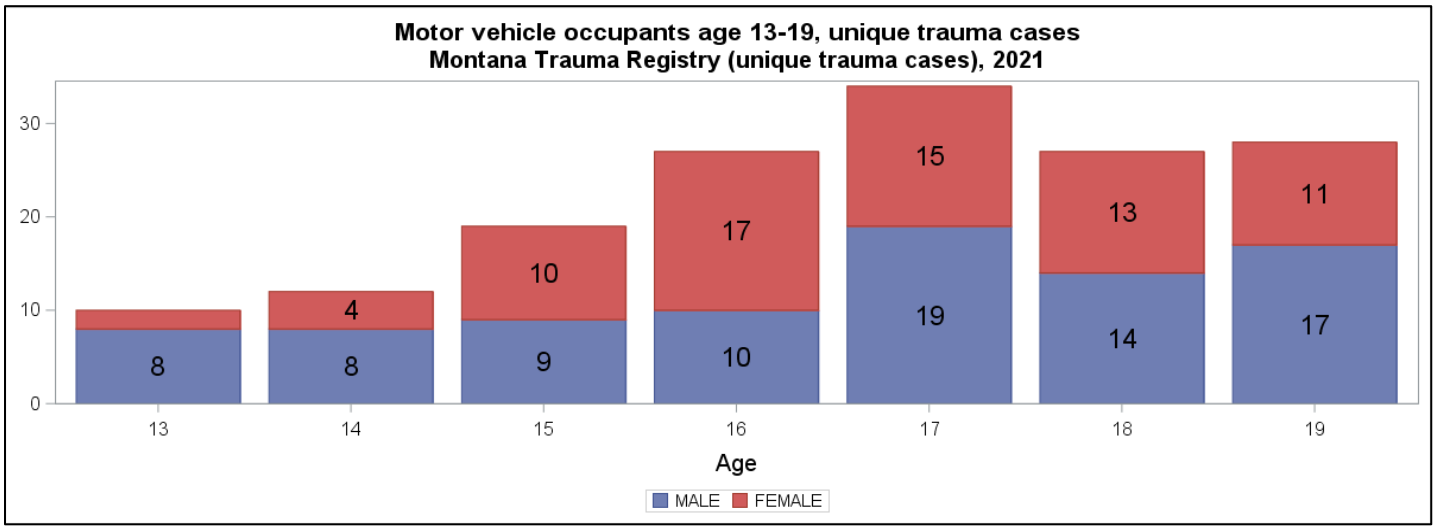
Figure 17. Drugs detected in transportation-related unique trauma cases with positive alcohol screen, 2021



TEEN MOTOR VEHICLE OCCUPANTS

There were 157 motor vehicle occupant injury cases among teens aged 13-19. 54% (N=85) were male and 46% (N=72) were female (**Figure 18**). Position in the vehicle was not documented for 97% (N=153).

Figure 18. Teen motor vehicle occupant injuries by age and sex, Unique trauma cases, 2021



Of 102 car, pickup truck, or van occupants, 85 had restraint use documented. 63% (N=54) of teens with known restraint use were unrestrained and almost half of the unrestrained teens had injuries with ISS>15. In comparison, 26% of teens that were restrained had ISS>15 injuries.

46% (N=73) of the 157 teen motor vehicle occupants tested negative for alcohol upon testing, while 20% (N=31) had alcohol in their blood test. 34% were not tested (**Table 18**). 38% (N=60) had any alcohol or illegal drugs detected upon testing.

Of the 60 teen cases with any alcohol or illegal drugs detected, 50 were car, pickup, or van occupants. 8% were restrained, 68% were unrestrained, and 24% had unknown restraint status.

Table 18. Alcohol use among teen motor vehicle occupants, Unique trauma cases, 2021

Alcohol Use	13-15 Years	16-19 years	All Ages
No (Not tested)	17	36	**53**
No (Confirmed by test)	21	52	**73**
Yes (Confirmed by test [Trace levels])	0	4	**4**
Yes (Confirmed by test [Beyond legal limit])	3	24	**27**
Total	**41**	**116**	**157**

FIREARM-RELATED TRAUMA[6]

In 2021, MTR captured 130 firearm-related trauma cases, 30 of which died in the health facility resulting in a CFR of 23%. Nearly 90% (N=112) of firearm-related trauma cases were males. 56% (N=73) involved a handgun, 19% (N=25) involved a rifle, shotgun, or larger firearm, and 24% involved other or unspecified firearms.

62% of the cases (N=80) were intentional injuries, including self-harm, assault, and legal/war (**Table 19**). The case fatality rate was highest for self-harm injuries at 53% (X^2=26.3, p<0.0001). Self-harm cases also had the lowest mean initial GCS of 6.5. Undetermined and legal/war firearm injuries resulted in the highest mean ISS. Self-harm cases resulted in the lowest functional independence measures (FIM) at discharge[7]. Assault injuries resulted in the longest average inpatient stays of 6.7 days (**Table 19**).

Table 19. Firearm injury outcomes by intent, unique trauma cases, 2021

Intent	Total N	Deaths	Case Fatality Rate	Mean ISS	Mean Inpatient LOS (Days)	Mean Initial ED GCS	FIM Score at discharge
Unintentional	35	2	5.7%	8.2	1.8	14.3	11.3
Self-harm/Suicide	32	17	53.1%	16.1	3.0	6.5	3.0
Assault/Homicide	43	5	11.6%	13.8	6.7	11.9	11.3
Undetermined	15	5	33.3%	20.1	3.8	11.8	10.5
Legal/War	5	1	20.0%	19.4	5.4	8.2	Missing
All	**130**	**30**	**23.1%**	**13.8**	**4.1**	**11.1**	**10.5**

[6] MTR final facility record's first or second external cause of injury code = ICD-10-CM codes W32.0, W32.1, W33.0, W33.1, W34.00, W34.09, W34.10, W34.19, X72, X73, X74.8, X74.9, X93, X94, X95.8, X95.9, Y38.4, Y22, Y23, Y24.8, Y24.9, Y35.00-Y35.03, Y35.09

[7] MTR uses a truncated form of the FIM score, including three items (self-feeding, locomotion, and verbal expression), each graded on a scale of 1 to 4 (1-full functional dependence, 2-partially dependent, 3-independent with device, 4-independent). A score of 12 would indicate fully independent.

UNINTENTIONAL FALL-RELATED TRAUMA[8]

There were 3,379 unintentional fall-related unique trauma cases in 2021. 57% (N=1,929) were females. 82% (N=2,786) were aged 55 or older. There were 130 in-hospital deaths due to falls for a CFR of 3.8% (3.2% for females and 4.7% for males). 78 patients had two or more separate fall-related cases captured in MTR during 2021 (the maximum for a single patient was 3). Most (96%) of the repeat fall patients were aged 55 and older. About 1 in 5 (N=627) fall-related cases involved an interfacility transfer. Table 20 shows outcomes for fall-related cases by interfacility transfer status.

Table 20. Outcomes for unintentional fall-related unique trauma cases, MTR 2021

Transfer status	Total N	Deaths	Case Fatality Rate	Mean ISS*	Mean Inpatient LOS (Days)*	Mean Initial ED GCS*	Mean FIM Score at Discharge*
Interfacility transfer	627	30	4.8%	11.0	5.6	14.1	10.4
No interfacility transfer	2,752	100	3.6%	8.4	4.4	14.7	10.4
All	**3,379**	**130**	**3.8%**	**8.9**	**4.6**	**14.6**	**10.4**

*at final treatment facility

Among patients aged 65 and older, over 65% of trauma cases were due to slipping, tripping, or stumbling falls (Table 21). 36% (N=862) of falls among age 65 and older involved a hip fracture. Almost all fall-related hip fracture patients had an ISS of 9 to 15 (98%, N=843).

18% (N=438) of falls among patients aged 65 and older involved a traumatic brain injury (TBI). 38% of fall-related TBI patients had an ISS > 15.

Among fall patients aged 65 and older with ISS>15, 76% involved a TBI.

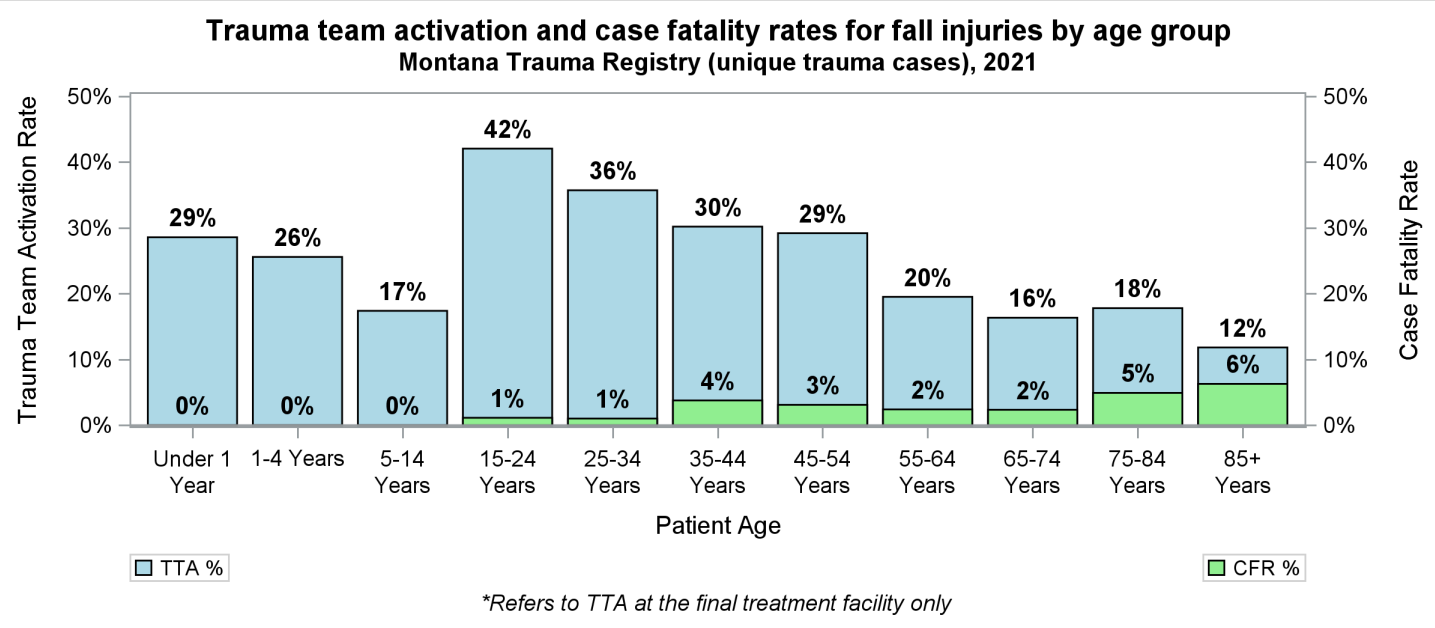
Table 21. Types of Falls among patients aged 55 and older, Unique trauma cases, 2021

	Type of Fall	N	%
1	Fall on same level from slipping, tripping and stumbling	1,149	48.5%
2	Other slipping, tripping and stumbling and falls	394	16.6%
3	Unspecified fall	227	9.6%
4	Fall on and from stairs and steps	209	8.8%
5	Fall due to ice and snow	86	3.6%
6	Fall from bed	75	3.2%
7	Fall on and from ladder	60	2.5%
8	Other fall from one level to another	55	2.3%
9	Fall from chair	41	1.7%
10	Fall from non-moving wheelchair, nonmotorized scooter and motorized mobility scooter	24	1.0%
	All top 10	2,320	97.8%
	Other	51	2.2%
	Total	**2,371**	**100.0%**

[8] MTR final facility record's first or second external cause code: ICD-10-CM code V00.11-V00.89 with 6th character=1, W00-W15, W17, W19, W16 with 6th character=2 (Except 16.4 and 16.9 with 5th character=2), W18.1, W18.2, W18.3 OR Intent/Mechanism fields indicate unintentional fall

Overall, 19% of fall cases had TTA at the final treatment facility, with variation by age group. Comparing TTA rates and case fatality rates (**Figure 19**) by age group reveals that older age groups (75-84, 85+) have the lower TTA rates despite having higher CFRs.

Figure 19. TTA rate and CFR for fall-related trauma by age group, Unique trauma cases, 2021



TRAUMATIC BRAIN INJURY (TBI)[9]

There were 1,390 TBI-related unique trauma cases reported in MTR during 2021 with 131 fatalities, resulting in a CFR of 9.4%. **Table 22** shows variation in CFR and other outcome measures by TBI severity level[10]. **Figure 20** shows variation in survival rates by TBI severity level.

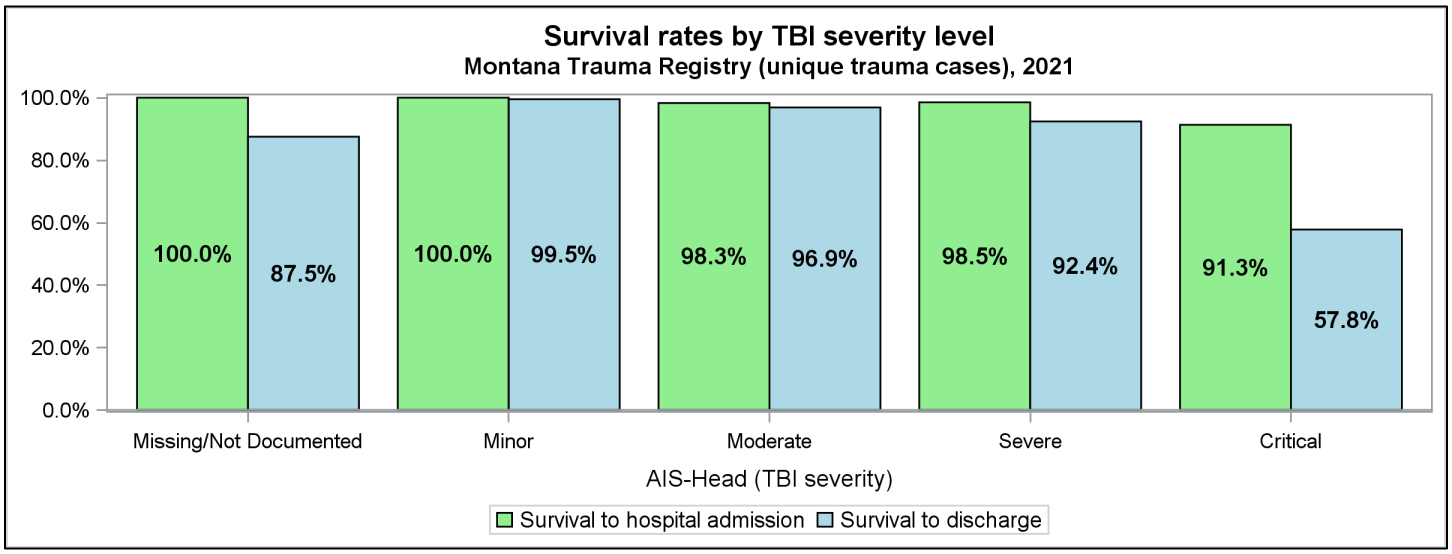
The main injury mechanisms leading to TBI were unintentional falls (50.1%), and unintentional transportation-related injuries (35.9%).

Table 22. Outcomes for TBI-related unique trauma cases by severity level, 2021

TBI severity	Total N	Deaths	Case fatality rate	Mean ISS*	Mean Inpatient LOS (Days)*	Mean Discharge GCS*	Mean FIM Score at Discharge*
Not documented	8	1	12.5%	4.3	1	14.8	10.3
Minor	200	1	0.5%	7.3	3.6	14.9	11
Moderate	351	11	3.1%	9.7	2.9	14.1	11
Severe	670	51	7.6%	16.3	5.3	13.3	9.8
Critical	161	68	42.2%	28.8	8	9	9.3
All	**1,390**	**132**	**9.5%**	**14.7**	**4.7**	**13.8**	**10.5**

*at final treatment facility

Figure 20. Survival rates by TBI severity, Unique trauma cases, 2021



1,051 TBI-related unique trauma cases were linked with at least one EMS record. EMS provider impression indicated a TBI-specific code in 44% of the linked cases (N=462). Among EMS records without a TBI-specific code, other commonly documented codes included “Injury-NOS (T14.90)”, “Acute pain due to trauma (G89.11)”, “Neuro/LOC-Altered Mental Status (R41.82)”. This can inform improved TBI surveillance using the EMS dataset.

In 2021, EMSTS initiated training for EMS agencies and hospitals on new TBI treatment, EPIC-MT. EPIC trains providers to avoid the 3 H’s (hyperventilation, hypoxia, and hypotension). EMS, as well as

[9] MTR final facility record diagnosis codes must include: S02.0, S02.1, S02.8X, S02.80, S02.81, S02.82, S02.91, S04.02, S04.03, S04.04, S06, S07.1 (7th character of A, B, or missing (reflects initial encounter, active treatment)
In the FY 2017 (effective Oct 1, 2016), S02.8 was expanded to include several subcodes (S02.80, S02.81, and S02.82) and the parent code S02.8X was retired. These subcodes should be included in the selection criteria for the indicator if using data for hospital discharges after Oct 1, 2016. In FY 2020 (effective Oct 1, 2019), S02.8 was expanded again to include S02.83, S02.84 and S02.85. These subcodes are NOT considered to be TBI (fractures to the medial/lateral orbital wall, or unspecified fractures of the orbit)
[10] TBI severity level based on Abbreviated Injury Scale (AIS)-Head: 1=Minor, 2=Moderate, 3-4=Severe, 5-6=Critical

facility-based care providers, are trained to recognize and manage these conditions to improve outcomes in severely injured TBI patients. To establish a baseline for assessing improvements over time, we used linked EMS and trauma data to assess documentation of hypotension and hypoxia across the care continuum. The figures below show differences in the level of hypotension and hypertension captured in the prehospital versus the MTR datasets. In most cases, using linked EMS and MTR data resulted in more complete results.

Figure 21. Percent of TBI-related trauma cases with at least one instance of Hypotension, by data source, Unique trauma cases linked with EMS, 2021

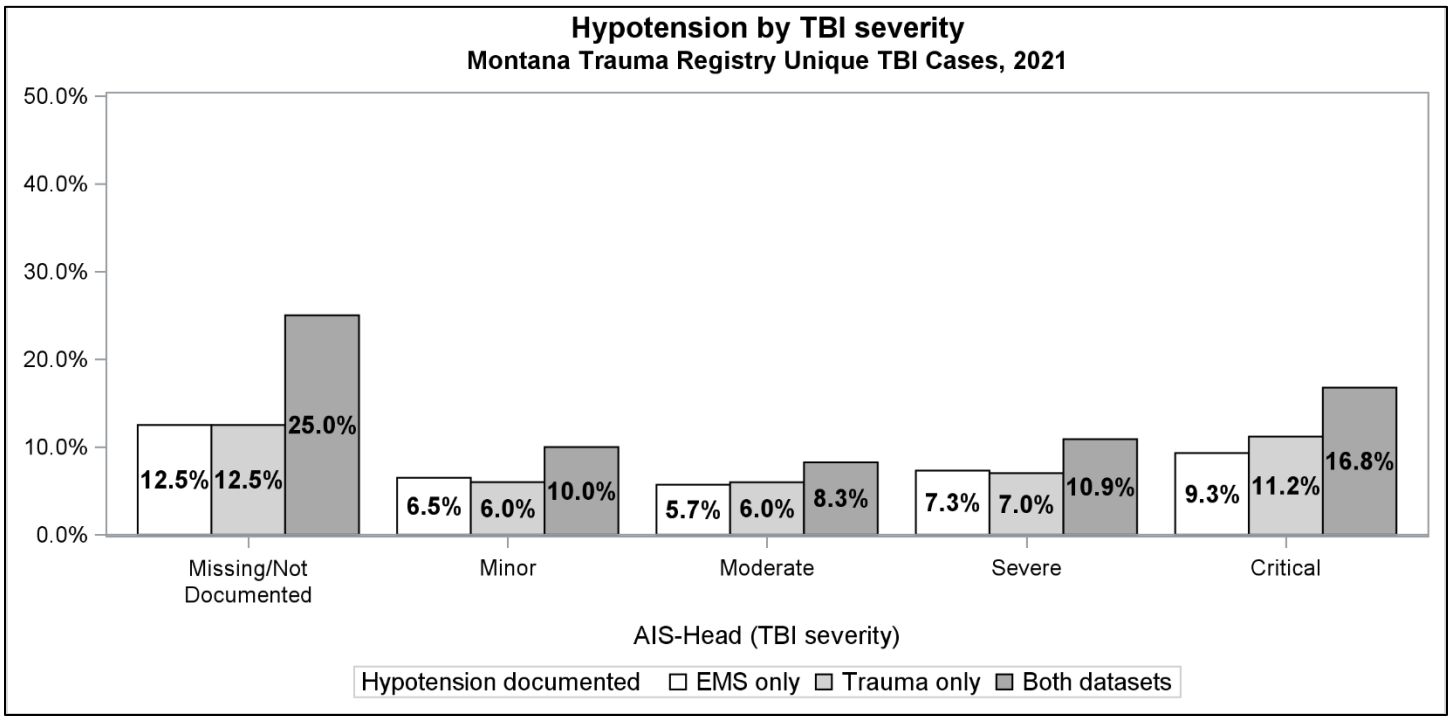
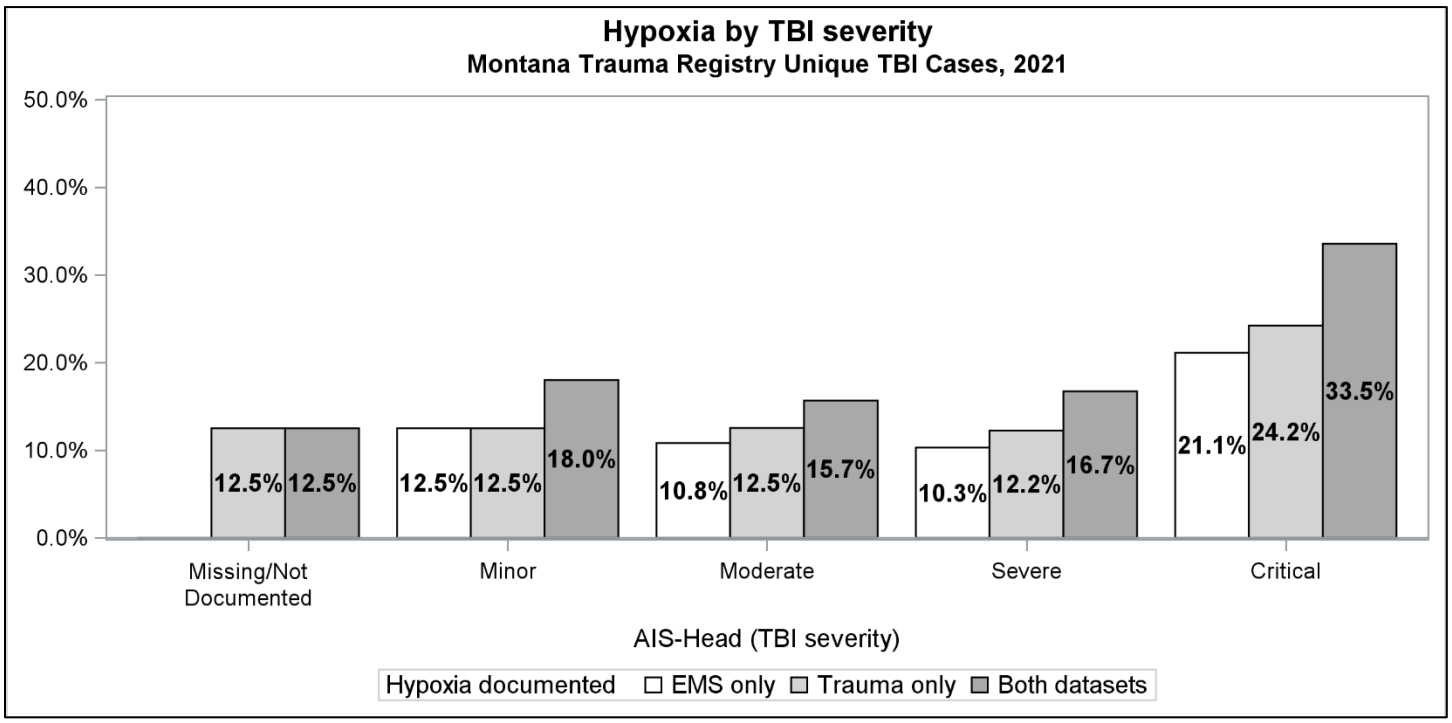


Figure 22. Percent of TBI-related trauma cases with at least one instance of Hypoxia, by data source, Unique trauma cases linked with EMS, 2021

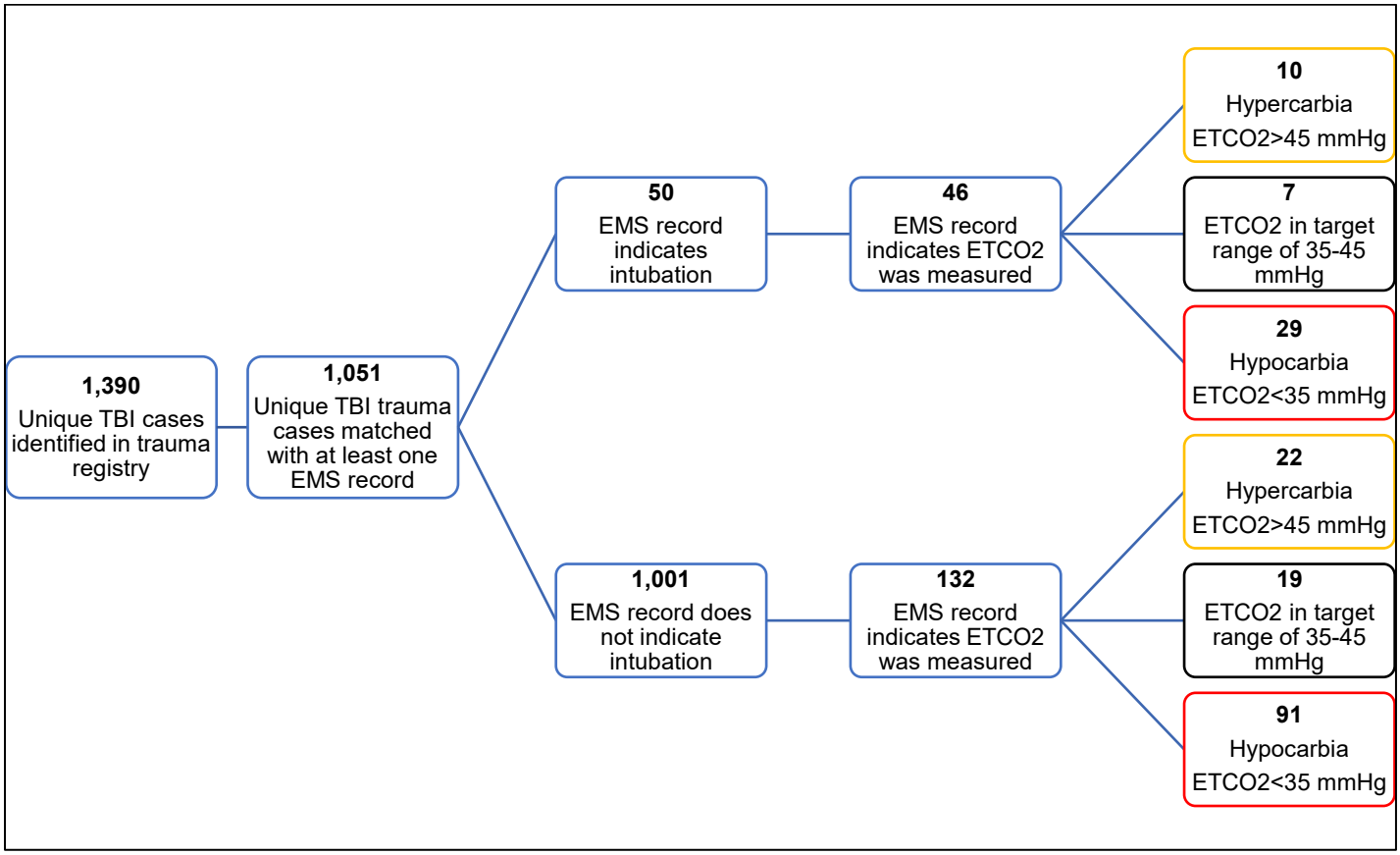


Hypotension is indicated by systolic blood pressure <90 mmHg. Among moderate TBI patients (N=351), 8.3% (N=29) had at least one instance of hypotension using linked EMS/trauma data (versus 6.0% using trauma dataset only, and 5.7% using EMS dataset only), while 10.9% of severe TBI patients (N=73/670) and 16.8% of critical TBI patients (N=27/161) had at least one hypotensive reading (using the linked dataset) (**Figure 21**).

Hypoxia is indicated by oxygen saturation below 90%. Among moderate TBI patients, 15.7% (N=55) had at least one instance of hypoxia (12.5% trauma data, 10.8% EMS data) (**Figure 22**). Using linked data, 16.7% (N=112) of severe TBI and 33.5% (N=54) of critical TBI patients had at least one instance of hypoxia.

Hyperventilation is indicated by end tidal carbon dioxide readings under 35 mmHg (hypocarbia, ETCO2 < 35 mmHg). Ideally, ventilation should be titrated to achieve ETCO2 between 35 and 45 mmHg. ETCO2 readings are not collected in the trauma registry dataset, therefore only data from the linked EMS records are used to assess hyperventilation. Of 1,051 TBI cases linked to EMS records, 50 EMS records indicated that the patient was intubated, 46 of which had ETCO2 measured, and hypocarbia was seen in 63.0% (N=29/46). Among the 1,001 EMS records that did not indicate intubation, 132 had ETCO2 measurements documented and 68.9% had hypocarbia (N=91/132) (**Figure 23**).

Figure 23. Unique TBI-related trauma cases with EMS intubation and ETCO2 measurement, 2021



APPENDIX 1. List of Facilities

Central Region

Facility	Designation Level
Benefis Healthcare, Great Falls	Regional Trauma Center
St. Peter's Hospital, Helena	Area Trauma Hospital *(As of 12/31/2021)*
Northern Montana Hospital, Havre	Community Trauma Hospital
Logan Health, Chester	Trauma Receiving Facility
Logan Health, Shelby	Trauma Receiving Facility
Mountainview Medical Center. White Sulphur	Trauma Receiving Facility
Logan Health, Conrad	Trauma Receiving Facility
Benefis Teton Medical Center, Chouteau	Trauma Receiving Facility
Big Sandy Medical Center, Big Sandy	Not Designated
*Billings Clinic Broadwater, Townsend	Not Designated
Missouri River Medical Center, Fort Benton	Not Designated
Logan Health, Cut Bank	Trauma Receiving Facility *(As of 12/31/2021)*
*PHS Indian Hospital - Browning	Not Designated
*PHS Indian Hospital - Harlem	Not Designated
*PHS Indian Hospital - Rocky Boy	Not Designated
Great Falls Clinic - Great Falls	Not Designated

Western Region

Facility	Designation Level
Providence St. Patrick Hospital, Missoula	Regional Trauma Hospital
Logan Health, Kalispell	Area Trauma Hospital
St. James Healthcare, Butte	Area Trauma Hospital
Clark Fork Valley Hospitals, Plains	Community Trauma Hospital
Logan Health, Whitefish	Community Trauma Hospital
Community Medical Center, Missoula	Community Trauma Hospital
Community Hospital of Anaconda, Anaconda	Community Trauma Hospital
Providence St. Joseph Hospital, Polson	Community Trauma Hospital *(As of 12/31/2021)*
St. Luke Community Healthcare, Ronan	Community Trauma Hospital
Barrett Hospital and Healthcare, Dillon	Trauma Receiving Facility
Deer Lodge Medical Center, Deer Lodge	Trauma Receiving Facility
Mineral Community Hospital, Superior	Trauma Receiving Facility
Ruby Valley Hospital, Sheridan	Trauma Receiving Facility
*Cabinet Peaks Medical Center, Libby	Not Designated
*Granite County Medical Center, Philipsburg	Not Designated
Bitterroot Health – Daly Hospital, Hamilton	Trauma Receiving Facility

Eastern Region

Facility	Designation Level
Billings Clinic, Billings	Regional Trauma Center
St. Vincent's Healthcare, Billings	Regional Trauma Center
Bozeman Health, Bozeman	Area Trauma Hospital
Central Montana Medical Center, Lewistown	Community Trauma Hospital
Livingston Healthcare, Livingston	Community Trauma Hospital
Beartooth Billings Clinic, Red Lodge	Trauma Receiving Facility
Big Horn County Hospital, Hardin	Trauma Receiving Facility

Facility	Designation Level
*Colstrip Medical Center, Colstrip	Not Designated
Madison Valley Medical Center, Ennis	Trauma Receiving Facility
Pioneer Medical Center, Big Timber	Trauma Receiving Facility
Prairie Community Hospital, Terry	Trauma Receiving Facility
Roosevelt Memorial Hospital, Culbertson	Trauma Receiving Facility
Sheridan Memorial Hospital, Plentywood	Trauma Receiving Facility
Stillwater Billings Clinic, Columbus	Trauma Receiving Facility
Trinity Hospital, Wolf Point	Trauma Receiving Facility
Northeast Montana Health Services, Poplar	Trauma Receiving Facility
Wheatland Memorial Hospital, Harlowton	Trauma Receiving Facility
Roundup Memorial Healthcare, Roundup	Trauma Receiving Facility
Holy Rosary Health Center, Miles City	Community Trauma Hospital
Daniels Memorial Hospital, Scobey	Trauma Receiving Facility
Rosebud Healthcare, Forsyth	Not Designated
Phillips County Medical Center, Malta	Not Designated
Dahl Memorial Healthcare, Ekalaka	Not Designated
*Fallon Medical Complex, Baker	Not Designated
*PHS Indian Hospital, Crow Agency	Not Designated
Frances Mahon Deaconess, Glasgow	Community Trauma Hospital
*Garfield County Medical Center, Jordan	Not Designated
Glendive Medical Center, Glendive	Not Designated
*Lame Deer Clinic, Lame Deer	Not Designated
McCone County Health Center, Circle	Not Designated
Sidney Health Center, Sidney	Not Designated
*Bozeman Health, Big Sky Medical Center	Not Designated
Powder River Medical Clinic, Broadus	Not Designated

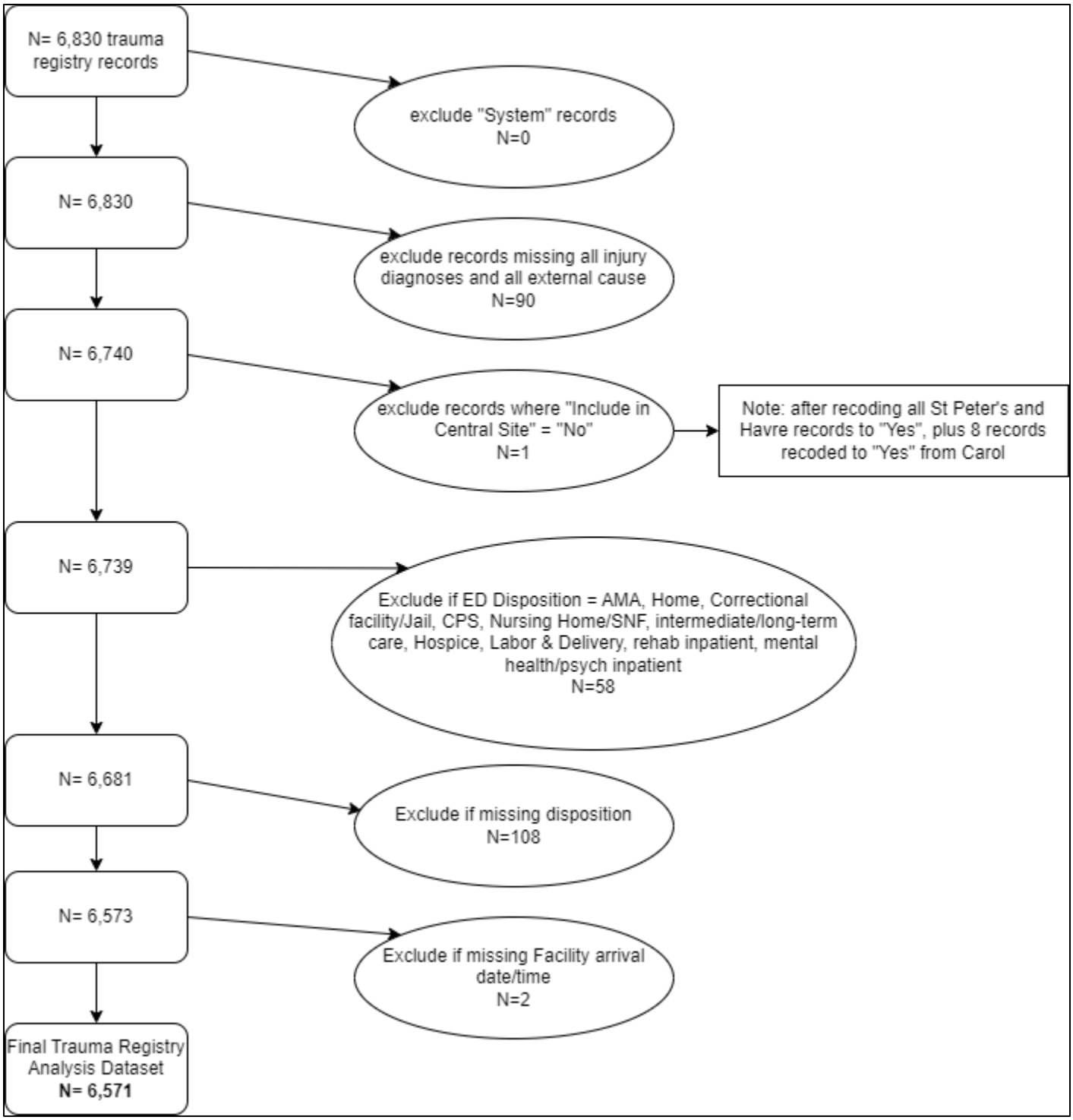
* denotes facility is not reporting

APPENDIX 2. Montana Trauma Registry 2021 Inclusion Criteria

All of the following conditions must be met for inclusion in MTR:

- Injury sustained within 14 days of initial encounter at health facility
- Assigned at least one of the following ICD-10-CM injury diagnosis codes
    - S00-S99 with 7th character modifiers of A, B, or C ONLY (anatomic injury – initial encounter)
        - Exclude if the only injury code is S00, S10, S20, S30, S40, S50, S60, S70, S80, S90 (isolated superficial injury)
    - T07 (unspecified multiple injuries)
    - T14 (injury to unspecified body region)
    - T20-T28 with 7th character modifier of A only (burns by specific body parts – initial encounter)
    - T30-T332 (burns by TBSA percentages)
    - T79.A1-T79.9A with 7th character modifier of A only (traumatic compartment syndrome)
- Must include one of the following:
    - Admitted as in-patient or observed patient for trauma
        - Exclude if admitted for monitoring a medical condition
        - Exclude if dismissed to home from ED
    - In-facility death resulting from traumatic injury
    - Patient transfer from one acute care hospital to another acute care hospital
        - Exclude transfer patients directly admitted with isolated injuries for elective and/or planned surgical intervention

APPENDIX 3. 2021 MTR analysis dataset inclusion/exclusions flowchart



APPENDIX 4. Trauma Dataset De-duplication

MTR receives records from facilities of various sizes across the state. In the case of an interfacility transfer, both the smaller (sending) and larger (receiving) facility may submit a record pertaining to the same patient. In order to avoid double-counting, we used MatchPro to de-duplicate the MTR dataset, linking together any records that represented the same patient case. Of 6,571 records, 21% (N=1,402) indicated that the patient was an incoming interfacility transfer patient meaning that there could be additional records in the registry for that patient case.

The fields used for linkage and method for computing similarity score (comparator) are shown below:

Receiving facility	Sending Facility	Comparator	Threshold Value (TV)	LProb	Summation
Immediate referring facility (R_FAC, R_FACLNK)	Submitting facility (TRK_FAC, TRK_FACLNK)	Jaccard (1)	0.80	0.75	Additive only
Facility arrival date (TRK_A_DATE)	Discharge date (O_D_DATE)	Date (Strict)	0.75	0.96	Additive only
Patient first name* (Z_NAME_F)	Patient first name (Z_NAME_F)	First Name	0.78	0.96	Default
Patient last name* (Z_NAME_L)	Patient last name (Z_NAME_L)	Last Name	0.78	0.94	Default
Patient middle name* (Z_NAME_M)	Patient middle name (Z_NAME_M)	Middle Name	0.78	0.50	Default
Last 4 digits of social security number (Z_SSN4)	Last 4 digits of social security number (Z_SSN4)	SSN	0.76	0.95	Default
Patient gender (D_GENDER)	Patient gender (D_GENDER)	Exact	1.00	0.98	Default
Patient birth date (D_DOB)	Patient birth date (D_DOB)	Date	0.75	0.96	Default

*For name comparison, we allowed for name shuffle (similarity threshold = 0.87) to catch cases where the first, middle, and/or last names were swapped. Names were not assigned value specific weights.

Field comparisons generating a similarity score below the TV were assigned the full disagreement (negative) score, while comparisons with a similarity score of 1 were assigned the full agreement (positive) score. Comparisons with a similarity score between the TV and 1 were given a partial score. Agreement and disagreement scores were weighted by the probability that two values agree/disagree for a pair of records that truly refer to the same entity (LProb), versus the probability that they agree/disagree for a pair of records that do not refer to the same entity (RProb, estimated based on frequencies observed in the data). Finally, scores across all fields were summed to give the linkage score for the record pair. Field comparisons using additive summation only affected the total linkage score if greater than or equal to zero, while those using default summation always affected the total.

Every record pair that agreed on at least 1 of the blocking keys (last 4 digits of SSN [SSN], first name [Soundex], last name [Soundex], birth date [Date: Year, Month + Day]) and that met the cutoff linkage score was included in the results set for manual review. The cutoff linkage score, or minimum score that a pair of records must achieve for the pair to be included in the results set, was dynamically adjusted by MatchPro based on an expected match percentage of 50% and desired PPV of 0.50. These parameters were selected to maximize sensitivity (avoid missing any true matches). Blocking reduces the number of record comparisons performed.

There were 961 record pairs, or potential matches, in the results set generated by MatchPro. These were manually reviewed to remove any non-matches or duplicate matches and identify double transfers (matches involving three records). The linkage process identified 715 record pairs and 1 triplet match, resulting in a total of 5,854 unique trauma cases in the de-duplicated MTR dataset.

APPENDIX 5. Trauma to EMS record linkage

We used probabilistic record linkage to link 2021 trauma registry records with 2021 EMS transport records. The probabilistic method attempts to simulate human reasoning by comparing several elements from the two datasets. The 2021 EMS dataset contained N=98,211 patient transport records and MTR contained N=6,571 nonduplicate records, with 4,245 indicating any EMS transport and 4,007 specifying a MT EMS agency transported the patient to the facility.

The linking variables we used were: NAME8 (first four characters of first name and last name), First Name, Last Name, DOB, Birth Year, Birth Month, Birth Day, Age (years), Sex, last 4 digits of SSN.

First we calculated the random matching probability $P_{(agree|unmatch)}$ with a lower bound of 1/N for each linking variable, or the probability that two randomly paired records matched on the respective variable. Simple random sampling without replacement was used to select N=400 trauma records and N=400 EMS records. Every record in the random trauma sample dataset was compared with every record in the random EMS sample dataset exactly once, to give a total of 79,800 random record pairs.

Next, we calculated the linked matching probability $P_{(agree|match)}$ with an upper bound of 1-1/N for each linking variable, or the probability that two deterministically linked records matched on respective variables. For the deterministic link, record pairs were required to match on the trauma record's submitting facility and EMS record's destination facility, and the trauma record's facility arrival date/time (trk_a_dt) had to be within same hour of EMS record's arrived at destination date/time (eTimes_11). In addition, at least 3 out of 4 (first name, last name, DOB, last 4 digits of SSN) had to match exactly. This resulted in N=3,273 deterministically linked record pairs.

Agreement and disagreement point values for each linking variable were calculated:

- Agreement points: $Log2[P_{(agree|match)}/ P_{(agree|unmatch)}]$
- Disagreement points: $Log2[P_{(Disagree|match)}/ P_{(Disagree|unmatch)}]$

If two records agree on a particular linking variable, that provides evidence that the two records refer to the same entity and the record pair is assigned some positive number of "agreement points". Fields with many distinct values, such as names or dates of birth, are worth more points than fields with few values, such as sex or race. If two records disagree on a linking variable, that is evidence that the two records do not refer the same entity, and the pair is assigned some negative number of "disagreement points". For disagreement points, fields that are very accurate/clean/reliable carry more weight. If one of the records in a pair is missing data on a linking variable, that provides no evidence either way (zero points are assigned for that field).

Linking variable	Matching probability Random pairs $P_{(agree|unmatch)}$	Matching probability Deterministically linked pairs $P_{(agree|match)}$	Disagreement points	Agreement Points
NAME8	0.00003	0.96642	-4.89604	15.2348
First Name	0.00386	0.96561	-4.85628	7.9668
Last Name	0.00054	0.96776	-4.95419	10.8106
DOB	0.00001	0.97741	-5.46798	16.2511
Birth Year	0.01240	0.99193	-6.93542	6.3221
Birth Month	0.08471	0.99435	-7.34029	3.5531
Birth Day	0.03242	0.98763	-6.28919	4.9288
Age (years)	0.01222	0.98817	-6.38392	6.3375
Sex	0.50354	0.98754	-5.31678	0.9718
SSN	0.00017	0.97472	-5.30557	12.5224

The next step was to perform the probabilistic record linkage. Every MTR record was compared with every EMS record, within the blocking parameters. For blocking, MTR "submitting facility" and EMS record "destination facility" must match, and MTR "facility arrival date" must be within 1 day before/after EMS record "incident date". For a given record pair, the comparison vector contained six values representing similarity between the two records on each of the six linking variables shown below:

MTR	EMS	Comparator Function	Threshold Value (TV)	Scoring Method	Summation
Name 8 characters (Z_NAME8)	Name 8 characters (NAME8)	Fx_GED SS= [1-(Generalized Edit Distance/Cutoff)]^3 Cutoff=500	0.2	Linear	Default
Last Name (Z_NAME_L)	Last Name (ePatient_02)	Fx_char_exact SS= 1- Levenshtein edit distance Cutoff=1	1	Binary	Additive only
Birth date (D_DOB)	Birth Date (ePatient_17)	Fx_Date_Compare SS= (year*log2(100)+month*log2(12)+day*log2(30))/ (log2(100)+log2(12)+log2(30)) where: year= 1 if match, 0 if non-match, month= 1 if match, 0 if non-match, day= 1 if match, 0 if non-match	0.5	Linear	Default
Age in years (D_AGE_INT)	Age in years (ePatient_15)	Only counted if DOB score is missing			
Sex (D_GENDER)	Sex (Ems_sex_numeric)	Fx_num_exact SS= **1**-(min(**1**,abs(param1-param2)))	1	Binary	Default
Last 4 digits of SSN (Z_SSN4)	Last 4 digits of SSN (SSN4)	Fx_GED SS= [1-(Generalized Edit Distance/Cutoff)]^3 Cutoff=200	0.1	Linear	Default

The value from the trauma registry was compared to the value from the EMS registry for each linking variable using the comparator function, which produced a similarity score (SS) ranging from 0 to 1 (where 1= exact match). The SS was then compared to the TV. With the linear scoring method, a partial agreement score is assigned for partial matches as long as SS ≥ TV. With the binary scoring method, the full agreement score is assigned to record pairs where SS ≥ TV. For both scoring methods, the full disagreement score is given if the threshold is not met (if SS < TV). Default score contribution means the score will always affect the total linkage score, and with additive score contribution, the score will only affect the total linkage score if it is a positive number. Finally, the 6 scores were summed to get the total match score for the record pair.

There were N=5,457 record pairs where Total_score >0 and N=4,775 record pairs where total score>13 (cut-off determined by manual review). Among these, there were N=320 duplicate TR matches (1 MTR record paired with multiple EMS records) and 1 duplicate EMS match (1 EMS record paired with multiple MTR records). The best match was selected with the following algorithm:

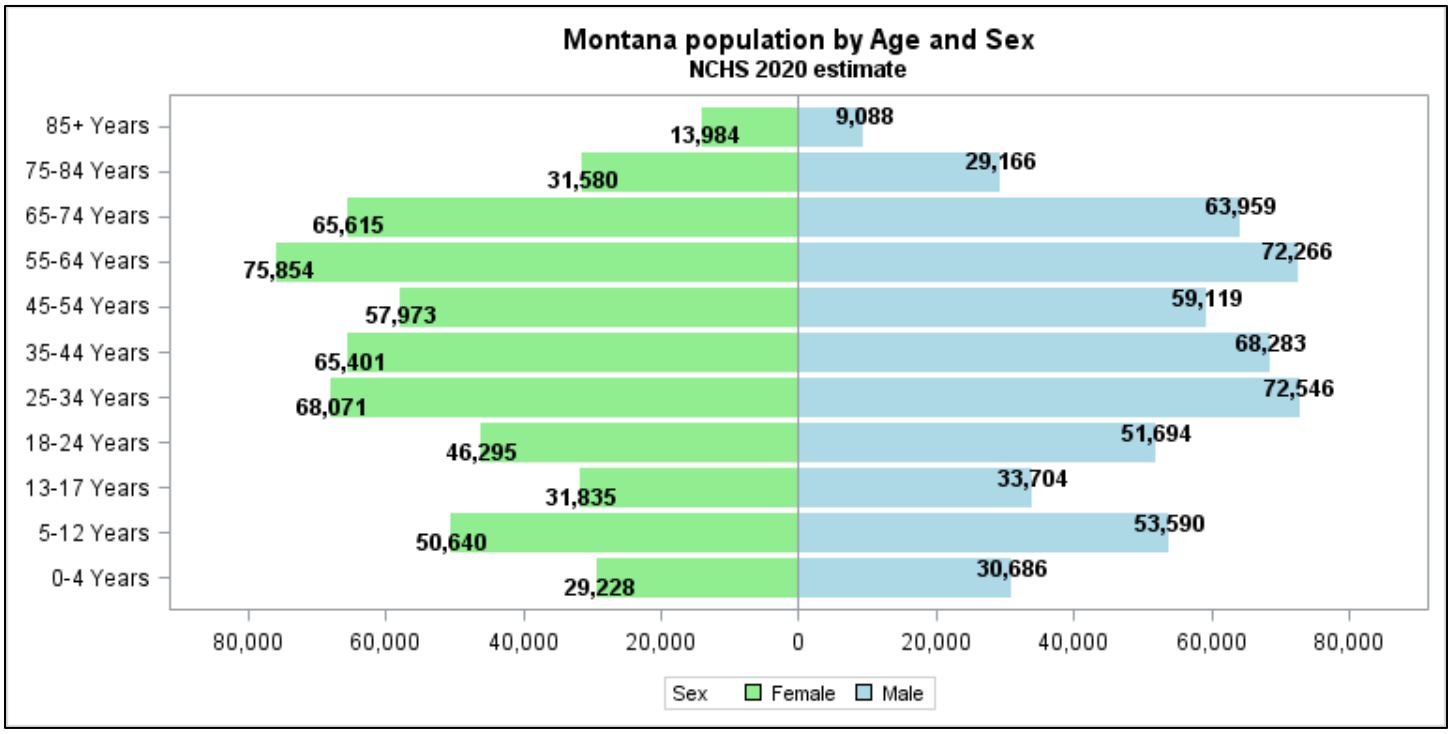
1. Select the pair where EMS record facility arrival time (eTimes_11) is closest to trauma arrival time (TRK_A_DT)
2. Select the pair with the highest total_score for probabilistic record linkage
3. Select the pair where EMS record incident time (incident_date_time) is closest to trauma arrival time (TRK_A_DT)
4. Select the pair with the least number of missing data elements

After removing duplicates there were N=4,454 unique trauma/EMS record pairs. This left 2,116 unmatched trauma records: 55 were interfacility transfer arrivals transported by a MT EMS agency, while 270 were 911/initial arrivals transported by an EMS agency. We then re-ran the same linkage algorithm for both types of unmatched trauma records, with different blocking parameters (EMS “response type” must match trauma record interfacility/initial arrival, and MTR “facility arrival date/time” must be within the same hour before/after EMS “arrived at destination date/time”). 5 interfacility matches and 46 initial arrival matches were found. The total number of unique trauma/EMS record pairs was 4,506.

- Matching Rate (any_ems): 4,506/4,245=106.1%
- Matching Rate (MT_ems): 4,506/4,007=112.5%
- Matching rate >100% is due to inaccurate documentation of EMS transport within MTR

Final trauma facility (A)	Trauma facility (B)	Trauma facility (C)	EMS (A)	EMS (B)	EMS (C)	N
X	X	X	X	X	X	1
X	X		X	X		405
X	X		X			241
X	X			X		36
X	X					33
X			X			3,417
X						1,721
Total unique trauma cases						**5,854**

APPENDIX 6. Montana Population Age-Sex Pyramid*



*2021 population estimates are not available as of 12/2022