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Posttraumatic Tube Thoracostomy: Risk Factors for Failure

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BACKGROUND AND SIGNIFICANCE

Thoracic injuries occur in approximately one third of trauma patients[1]. Injuries to pulmonary parenchyma via blunt or penetrating trauma frequently result in hemo-pneumothorax requiring tube thoracostomy. The standard of care for initial treatment of a posttraumatic chest injury resulting in posttraumatic effusion, with or without a pneumothorax, is the placement of a large caliber chest tube[2].

Trauma patients have unique risk factors for the development of pleural space infections, one of which is placement of one or more chest tubes. Tube thoracostomy carries the inherent risk of potential inoculation of the pleural space[3]. Penetrating injury also increases the likelihood of a pulmonary infection, as the penetrating object may transfer infectious material into the thoracic cavity and lead to tissue destruction. Many trauma patients require prolonged courses of mechanical ventilation, which is an independent risk factor for pneumonia, known to contribute to pulmonary effusion that can progress to empyema. Moreover, multi-trauma patients with concomitant abdominal solid or hollow viscus injury or diaphragmatic violation are at greater risk for the development of persistent pleural effusion and empyema[4].

The placement of a chest tube often does not completely drain a post-traumatic effusion that is typically a collection of blood in the pleural space. Retained hemothorax may be central to the pathogenesis of posttraumatic empyema[3]. The combination of undrained blood in the chest cavity with exposure to pathogenic bacteria from external or internal contamination provides the optimal milieu for the formation of the thick fibrinous exudate that characterizes an organized empyema, sometimes called “fibrothorax”, or “trapped lung”[5].

There are generally accepted to be three stages in the evolution of empyema[2]. Stage 1, also called the exudative phase, responds to thoracentesis or chest tube drainage alone. In stage 2, the fibrinopurulent stage, the previously sterile pleural effusion becomes infected, leading to the accumulation of inflammatory cells, fibrin, and debris. The fluid becomes more viscous and fibrin deposition may lead to multiple loculations. The net effect is to make drainage more difficult; however, empyema in the fibrinopurulent stage may still be amenable to chest tube drainage.

The transition from stage 1 to 2 may occur quickly, often within twenty-four to forty-eight hours. A thick, inelastic pleural peel, or rind, that traps and compresses the lung, characterizes stage 3 empyema (organizing empyema). Knowing the stage of the empyema can be critical to the choice of treatment modality, as a stage 3 empyema frequently will not respond to any other modality outside of surgical debridement of the pleural peel[4].

There is considerable debate in the literature about the optimal treatment of posttraumatic pleural effusions that do not resolve after placement of a large bore pleural drain. Available treatment options include placement of additional large bore thoracostomy tubes, the use of smaller bore image-directed pleural catheters, infusion of intrapleural fibrinolytics, thoracoscopic drainage by video assisted thoracoscopic surgery (VATS), or traditional open thoracotomy with decortication[5]. Most often, a combination of additional small or large bore drainage tubes with or without fibrinolytics is used initially in an effort to avoid performing the latter two surgical procedures[6].

Success rates with less invasive modalities have proven to be highly variable. A recent study found that the use of Streptokinase for drainage of empyema does not improve outcomes or length of hospital stay[7]. Another study found that the use of percutaneous pleural pigtail catheters in children, while efficacious for draining serous pleural effusions, were less effective for draining hemothorax, and were not effective for draining empyema[8].

The variability of success with non-surgical modalities may be related to the stage of the empyema at diagnosis[5], making accurate diagnosis and staging of empyema critical to determining the most effective treatment modality. However, the ability to accurately diagnose the stage of empyema with imaging techniques is unreliable at best, and subject to variable interpretation[5]. This may become more problematic when there is a concomitant pneumonia complicating the clinical and diagnostic picture.

Criteria for the diagnosis of empyema (in any stage) vary from institution to institution[2-11,14-16]. It has been suggested that the presence of a pleural peel on CT scan is indicative of a stage 3 empyema, and uniformly predicts the failure of non-operative treatment[5]. However, in that same series, chest CT missed the presence of a pleural peel in 17 of the 31 patients who were documented to have a significant pleural peel at the time of thoracotomy. The ability to radiographically distinguish an exudative stage 2 empyema from any other type of fluid collection is limited, which in turn may delay definitive and appropriate treatment.

The University of New Mexico Hospital (UNMH), a Level I trauma center, cares for approximately 150-200 trauma patients annually that have significant chest injuries requiring tube thoracostomy. At UNMH, surgeons on the Trauma Service place and manage all posttraumatic thoracostomy tubes, utilizing large bore tubes (34 or 36 Fr for adults) under sterile conditions. Currently at UNMH, there is no definitive algorithm for the management of persistent posttraumatic pleural effusions that fail initial tube thoracostomy.

This paper describes the preliminary results of an ongoing study evaluating variables for all patients receiving tube thoracostomy after traumatic chest injury. The purpose of the study is to analyze the risk factors for failure of primary tube thoracostomy, to determine the outcomes for various treatment modalities subsequently employed, and to correlate the diagnostic modalities used.

MATERIALS AND METHODS

This was a retrospective study of patients who required tube thoracostomy in the management of traumatic chest injury and was approved by the Human Research and Review Committee at the University of New Mexico. The trauma registry database at the University of New Mexico Hospital, a Level I trauma center, was queried for all patients that were admitted between January 2003 and December 2003 and required the placement of a chest tube after a traumatic chest injury.

Each patient's medical paper chart was cross-referenced with his or her computer records to gather the following data: patient demographics, Injury Severity Score (ISS), type of chest trauma, presence of abdominal or diaphragmatic injuries, any operations performed on admission, the indication and duration of each thoracostomy tube, the presence of retained fluid after tube placement was noted, and the need for and the duration of mechanical ventilation. If pneumonia was diagnosed, the results of cultures, and choice of antibiotics was recorded. When further treatments (additional thoracostomy tubes, percutaneous catheters, fibrinolytics, VATS, thoracotomy) were required, the sequence of events, timing, and efficacy was noted. Total number of chest tubes placed and whether the tube was placed in an outside facility, in the field, in the Emergency Department, or at the patient's bedside was also recorded. For patients who ultimately required either traditional or video assisted thoracotomy with decortication, other modalities that were employed prior to surgery were noted, as well as whether the patient failed video assisted thoracotomy prior to undergoing an open thoracotomy with decortication. Total hospital days and ICU length of service were also documented.

DEFINITIONS:

Significant traumatic chest injury was defined as an injury (hemothorax, pneumothorax, or hemo-pneumothorax) requiring invasive intervention (chest tube, thoracotomy, VATS).

Posttraumatic effusion is defined as the presence of pleural effusion as read by a radiologist on the admission chest X-ray or CT scan after admission for trauma.

Retained fluid was defined as the presence or persistence of a pleural effusion after placement of a chest tube.

The diagnosis of empyema required one of the following: (1) Purulent pleural fluid, documented by the presence of WBCs on gram stain at thoracentesis, chest tube or pleural catheter insertion, or at thoracotomy, (2) the presence of an inflammatory pleural peel at thoracotomy or VATS; or (3) radiographic finding of loculated pleural fluid collections or septated pleural fluid collections, or the presence of thickened or contrast enhancing pleura on chest CT scan or CXR.

Pneumonia was diagnosed if gram stain and respiratory culture of the patient's sputum or BAL were positive for a predominant organism, and if the following clinical criteria were present: a new infiltrate on CXR; signs of a systemic infection, (i.e., leukocytosis or body temperature of 38.5 degrees C or higher); increased tracheobronchial secretions, and a deterioration of pulmonary status as manifested by increasing oxygen requirement.

Chest tube drainage success was defined as either complete drainage of pleural effusion or incomplete drainage of pleural effusion but concomitant improvement in clinical signs of infection without the need for employing a secondary modality. Chest tube drainage failure was defined as requirement of a secondary modality. A secondary modality was defined as the placement of additional large or smaller caliber chest tubes or percutaneous catheters specifically for a persistent effusion, VATS, or open thoracotomy.

Because this is a report of preliminary data for an observational study, all data will be reported in terms of percentages and discreet values to delineate trends that were observed.

RESULTS

During the year 2003, there were 156 patients who required tube thoracostomy after a traumatic chest injury, 43 patients (27.6%) had penetrating injuries and 113 (72.4%) had a blunt mechanism of injury. All patients had at least one chest tube placed. The average age of the patients was 37.2 years. There were 38 females (24.0%) and 118 males (76.0%). Injury Severity Scores (ISS) averaged 21 with a range of 9 to 54. There were a total of 263 chest tubes placed during this time period, including those small caliber tubes that were placed by interventional radiology (IR) under computed tomography guidance. The average number of chest tubes per patient was 1.7 tubes. The average length of stay (LOS) after admission was 13.6 days. One hundred and seven patients (68.6%) had successful primary tube thoracostomy and 49 patients (31.4%) required a secondary intervention and were termed failures of primary tube thoracostomy. Death occurred in 12 patients and was not directly related to complications of chest tube placement in any of the twelve.

Table 1. Demographic Data of Patients with Chest Tubes (n= 156)

Characteristics	Mean	Range
Age, years	37.2	(7-99)
ISS	21	(9-54)
LOS	13.7	(1-74)
Tube Thoracostomy (including IR)	263	
Average Number, per patient	1.7	(1-8)
Average Duration, days	5.7	(1-18)
Mechanism of Injury	Mean	Percent
Penetrating	43	27.6%
Blunt	113	72.4%
Success of Primary Tube Thoracostomy	107	68.6%
Failure of Primary Tube Thoracostomy	49	31.4%
Deaths	12	7.7%

ISS = Injury Severity Scale, LOS = Length of Stay

Table 2. Characteristics of Patients with Successful and Failed Tube Thoracostomy with Empyema.

Patient Characteristics	Success (n=107)	Failure (n=49)	Empyema (n=17)
Average Age	36.3	37.5	38.3
% blunt chest trauma	74.8	65.3	70.6
# PTX (%) # HTX or HPTX (%)	58 (54.2) 49 (45.8)	14 (28.6) 35 (71.4)	3 (17.6) 14 (82.4)
% with retained fluid	55.1	77.8	85.7
% pts w/abx prior to CT	16	14	23.5
Avg. # CT/patient	1.2	2.8	3.4
% Intubated	47.7	79.6	64.7
Avg. # of vent days	4.6	8.6	14.7
Avg. # hospital days	12	17	27
% with Pneumonia	22.4	42.8	64.7
Average ISS	19	24	24
% Bacteremia	0.97	10.2	17.6
% with Abdominal or Diaphragm Injury	25.2	32.7	29.4
# Deaths	0	12	1

PTX=pneumothorax, HTX=hemothorax, HPTX=hemopneumothorax

There were 107 patients in the success group. They had an average age of 36.3 years and there were 80 males and 27 females. Eighty of these patients had blunt chest trauma (74.8%) and 27 had penetrating trauma (25.2%). The indication for chest tube in 58 patients was pneumothorax (54.2%) and in 49 patients, the indication was either HTX or HPTX (45.8%). Twenty-seven of the 49 patients with HTX or HPTX had retained fluid on the first chest x-ray after the placement of the chest tube (55.1%). The average number of chest tubes per patient was 1.2 for the patients in the success group. Fifty-one patients (47.7%) in this group were intubated with the average number of vent days totaling 4.6 days. Pneumonia was diagnosed in 24 patients (22.4%). Twenty-seven patients were found to have abdominal injuries (25.2%), and 1 patient had bacteremia documented by blood culture (0.97%). The average Injury Severity Score (ISS) was 19.

There were 49 patients in the failure group. The average age was 37.5 years and there were 37 males and 12 females. Thirty-two patients (65.3%) sustained blunt chest trauma, while the remaining 17 patients sustained penetrating injuries (34.9%). The indication for chest tube in 14 patients was PTX (28.6%), and in the remaining 36, the indication was HTX or HPTX (71.4%). Twenty-eight of the 36 patients with HTX/HPTX had retained fluid after placement of the chest tube for that indication (77.8%). Seven received antibiotics prior to chest tube insertion (14%). There was an average of 2.8 chest tubes placed per patient in this group. Thirty-nine (79.6%) of the patients were intubated and remained mechanically ventilated for and average of 8.6 days. Pneumonia was diagnosed in 21 patients (42.8%). Sixteen patients (32.7%) were found to have concomitant abdominal or diaphragmatic injuries. Five patients had bacteremia (10.2%). The average ISS was 24.

The patients in the empyema group are a subset of the failure group. There were a total of 17 patients that went on to have empyema (all stages). The average age was 38.3 years, with 5 females and 12 males in the group. Twelve patients had blunt trauma (70.6%) and 5 had penetrating trauma (29.4%). PTX was the indication for thoracostomy in 3 patients (17.6%) and the remaining 14 had a chest tube placed for HTX or HPTX (82.4%). Twelve of the patients who had chest tubes placed for HTX or HPTX (85.7%) had retained hemothorax after placement of the chest tube on the same side as the empyema. Four patients (23.5%) received antibiotics prior to the placement of that chest tube. The average number of chest tubes in this group was 3.4 per patient. Eleven patients were intubated (64.7%) with the average number of ventilator days totaling 14.7 per patient. A diagnosis of pneumonia was made in 11 patients (64.7%) and bacteremia occurred in 3 (17.6%). Abdominal injuries were found in 5 patients (29.4%). The average ISS was 24.

Of the 49 patients who did not have successful primary tube thoracostomy, 12 died (8 within 48 hours of their injuries, 1 from complications of malignancy, 2 after the family decided to withdraw support, and 1 from overwhelming sepsis). Of those 36 patients who survived and who required secondary interventions, 16 patients had resolution of the effusion after receiving only additional large bore chest tubes as their secondary intervention. One patient required fibrinolytics to be instilled into a large bore catheter as the only secondary intervention prior to resolution. The remaining 19 surviving patients that failed primary and secondary large bore tube thoracostomy required additional interventions as shown in Table 2.

Table 3. Secondary Interventions for Patients Failing Primary Tube Thoracostomy

	Total	Percent
Patients requiring secondary interventions (does not include those who died)	36/156	23.1%
Patients requiring secondary large bore CT only	16/36	44.4%
Patients requiring CT+lytics	1/36	2.7%
Patients receiving IR drainage	9/36	
CT+IR (without lytics or other modality)	5/36	13.8%
CT+IR+lytics+VATS or Thoracotomy	2/36	5.6%
CT+IR+VATS or Thoracotomy	2/36	5.6%
Patients undergoing surgical treatment after primary and/or secondary tube thoracostomy failure	10/36	
CT+VATS only	5/36	13.8%
CT+VATS and Thoracotomy	1/36	2.7%
CT+Thoracotomy only	4/36	11.1%

A total of 9 patients received IR drainage in addition to at least one large bore thoracostomy tube. This was successful in 5 patients and failed in 4 patients. Of the 4 patients that failed IR drainage, 2 received fibrinolytics and then ultimately required thoracotomy, 1 went directly to thoracotomy after IR drainage failed, and 1 underwent VATS after initial failure of IR drainage.

Six patients underwent VATS immediately after primary chest tube failure. One of the 6 patients was found to have a retained hemothorax, 1 had persistent air leak, and 4 were treated for empyema. One of the 4 patients that underwent VATS for empyema had to be converted to open thoracotomy. There were 4 patients that had open thoracotomy performed as the only secondary intervention. Three of the 4 patients had massive hemothorax, which was not amenable to resolution with chest tubes, and underwent the thoracotomy upon admission, and 1 had a retained hemothorax.

Table. Characteristics of patients with empyema (n=17)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	total
Dx Modality																		
Tissue cx		x				x	x		x		x	x		x		x	x	9/17
OR peel						x								x				2/17
CT peel								x				x				x		3/17
Pleural pus			x	x	x			x			x					x		6/17
Loculations	x	x	x		x		x			x			x	x			x	9/17
Radiol. dx						x		x				x						3/17

Table 4 summarizes the modalities used in the diagnosis of empyema and if a radiologist diagnosed empyema based on the radiographic findings. Three of the 17 patients were diagnosed by a radiologist. One of those 3 was diagnosed after placement of an IR drain revealed a positive fluid culture, and the other 2 were diagnosed by the presence of a pleural peel on CT scan. Because not every patient was treated surgically, we cannot know which patients had a pleural peel upon presentation to the operating room. However, of the 3 patients who had a pleural peel on CT scan, none were noted to have a pleural peel upon surgical intervention. Loculations were present on either CT scan or chest x-ray in 8 of the 17 patients, purulent pleural fluid in 6 of the 17, and a tissue diagnosis was made in 9 of 17 patients.

DISCUSSION

Despite protocol at UNMH, which requires placement of chest tubes under sterile conditions by general surgery residents with supervision, we found that successful outcome of primary tube thoracostomy occurs in only 68.6% of patients who require a chest tube as a result of chest trauma. The remaining 31.4% who fail primary tube thoracostomy receive additional treatment modalities and, in general, require longer hospital stays.

Several studies have retrospectively determined individual risk factors for failure of tube thoracostomy[3-7, 16]. We wanted to confirm that the patient population that failed primary tube thoracostomy at our institution would demonstrate similar observable trends that would indicate the validity of those risk factors. We did observe that patients in the failure group collectively demonstrated trends were previously noted in the literature to be individual risk factors for chest tube failure.

Those patients that failed primary tube thoracostomy tended to have more penetrating chest trauma, were more likely to have required a chest tube for hemothorax (with or without pneumothorax), and tended to retain that hemothorax more often than the group that had successful tube thoracostomy. They received antibiotics prior to placement of the first chest tube less often than the failure group, although they were more likely to have had pneumonia and/or bacteremia. Also, they tended to have more concomitant abdominal or diaphragm injuries, were more likely to require intubation, and tended to have longer duration of mechanical ventilation and hospitalization.

Although it is difficult to infer causality of chest tube failure from any of these risk factors, we may be able to infer that patients who exhibit these characteristics should be more carefully monitored for diminishing chest tube output, and should have more aggressive treatments instituted sooner.

As noted above, the patients in the failure group who went on to develop empyema tended to reflect the trends seen for the failure group in general. However, there were some notable exceptions. While the authors acknowledge that the percentage of the patient population studied who went on to develop empyema was small (10.9%), there were observable trends in that group when compared to the group that failed primary tube thoracostomy that warrant further discussion because they do not correlate with the literature.

First, a larger percentage of patients with empyema got antibiotics than did either the success or the failure group. This is compelling because it has been suggested that patients receiving chest tubes routinely receive prophylactic antibiotics[3] to prevent pleural space infections and sepsis. Our observation may attest to the inefficacy of antibiotics for treatment of empyema once it has progressed past the fibrinopurulent stage. To determine whether our observation signified this conclusion, it would be necessary to include a tissue diagnosis for every patient with empyema to determine whether they had progressed past the fibrinopurulent stage. Because tissue diagnosis is not done routinely at our institution, it would be necessary to design a prospective study with routine tissue sampling for every patient with suspected empyema. Additional, our study was designed to assess the same information for every chest tube placed, including smaller bore IR drains and drains placed after the primary chest tube had failed. Our observation regarding administration of antibiotics before placement of thoracostomy tubes may also reflect the fact that the patients with empyema were more likely to have a diagnosed pneumonia or other suspected infection for which they were already receiving prophylactic antibiotics at the time of the additional chest tube placements.

Second, the empyema group was less likely to have concomitant abdominal or diaphragmatic injuries than the failure group. Despite a body of literature that cites inflammatory processes within the abdominal cavity as being a risk factor for nontrauma patients in the development of empyema[4, 10], it appears that this does not hold true for trauma patients. Our observation may reflect the nature of the abdominal and diaphragmatic injuries that trauma patients sustain, and that these injuries are almost always repaired immediately, and do not form the foci of abscess that may develop in a nontrauma patient as a result of a remote cholecystectomy or splenectomy, both of which are cited as common sources of intraabdominal abscess.

Third, because the ISS was observed to be exactly the same for the empyema group as the failure group, the authors are lead to believe that there is a contributing risk factor among trauma patients who develop empyema that is independent of the severity of their injuries.

Finally, although the empyema group tended to have longer LOS and more mechanical ventilation days, there were a smaller percentage that were intubated. This seems counterintuitive. We interpreted this tendency to mean that simply the requirement for intubation may not be an independent risk factor for empyema and that perhaps the longer LOS and mechanical ventilation days for this patient population were secondary to the empyema itself.

The most consistent difficulty that we encountered in the collection of data was the inconsistency of the method of diagnosis and the lack of correlation with tissue diagnosis and pathologic findings to radiographic findings. The single most compelling observation that we were able to make was that in the process of diagnosing empyema, much emphasis was placed on the presence of a pleural peel on CT scan, when in fact, that radiographic finding was present in less than 18% of patients that were diagnosed with empyema through other diagnostic modalities. This observation corresponds to conclusions previously noted by other authors who suspect that the presence of a pleural peel on CT scan, which is part of the diagnostic criteria that radiology uses to diagnose empyema, is infrequently encountered[4, 15.]

Another objective of this study was to delineate the success of current management strategies in the treatment of posttraumatic empyema. Because there were only 3 patients that received fibrinolytics, it would be difficult to assess for a pattern in the use of this modality, other than to state that it is not frequently used by the trauma surgeons in the management of persistent pleural effusions. However, of note, both of the 2 patients who were infused with fibrinolytics through IR catheters went on to need open thoracotomy. The only patient who was successfully treated with fibrinolytics was infused through a large-bore chest tube.

IR drains were used to drain fluid collections, but were successful in only 5 of the 9 patients who were treated in this fashion. Again, the sample size is small. However, it may be suggested that small-bore percutaneous catheters are not consistently successful enough to recommend their routine use prior to VATS or open thoracotomy. VATS for empyema was successful in 4 of the 5 patients for whom it was employed in the treatment of empyema and was uniformly successful when employed for retained hemothorax or persistent air leak. Open thoracotomy was performed in 7 patients without attempting to perform VATS first based on attending physician preference. Four open procedures were done for empyema and 3 were done for hemothorax. There was only 1 conversion from VATS to open thoracotomy for empyema. All 7 open thoracotomies were successful in the treatment of empyema.

Although the sample size was extremely small, the authors feel that we are beginning to observe trends that will be maintained with a larger sample size and that when the final data analysis is complete, we will be able to make recommendations for optimal treatment of posttraumatic empyema.

CONCLUSIONS

The utility in any observational study that assesses for risk factors in the progression of any disease entity is to attempt to identify those risk factors that can be modified or prevented. Without the benefit of larger numbers of patients and a control group, it may be difficult to make specific recommendations about the diagnosis and treatment of posttraumatic empyema based on the information gathered. However, because we observed certain trends that correlated well with accepted literature, the authors feel that we can make some general statements about the successful management of tube thoracostomy.

1. Aggressive and thorough drainage of blood in the chest cavity should be the primary goal for any trauma patient with pleural effusion on chest x-ray after trauma. The presence of retained hemothorax was the strongest trend that we observed among patients with primary failure. Unlike medical patients, who may have a myriad of reasons to have serous fluid in the pleural space (malignancy, CHF, pneumonia, cirrhosis), there is an excellent chance that patients sustaining blunt or penetrating trauma to the chest will have a pleural effusion that consists of blood.

2. Early, and accurate, diagnosis and treatment of ventilator-associated pneumonia and bacteremia, although not proven to prevent seeding of the pleural space, may decrease overall length of hospital stay and diminish ventilator dependence. Further analysis of patients with empyema, and how these entities affect the development of empyema is warranted.

3. In the diagnosis of empyema, it may be more important to rely on the patient’s clinical presentation in conjunction with non-radiographic and radiographic diagnostic modalities than to rely exclusively on the elusive radiographic finding of a pleural peel, which is often either not present or is not interpreted as that. It will be very important in the next phase of this ongoing study to delineate which radiographic modalities

were employed, and how well they correlate to tissue diagnosis and intraoperative findings. With such a small sample size in the empyema group, we can only speak to our observations for the preliminary findings.

4. Although we often use "less invasive" treatment modalities such as IR drains and fibrinolytics, several studies have advocated for the early use of VATS in the treatment of empyema in the fibrinopurulent stage, as well as for retained hemothorax and persistent air leak[1,6,11-13,15]. It may be that although IR drainage is successful some of the time, when it is not successful, this translates into more hospital days and cost to the patient, as well as more lifetime exposure to radiation through repeated CT scans and chest x-rays. It has been suggested that perhaps once a pleural effusion has become loculated, that it should be treated with VATS and not be attempted to drain with percutaneous pigtail catheters[6, 8,11,12-14]. A prospective study would help to define the role of IR drainage in the setting of empyema.

Without question, the limitations of this study are those of an observational study with preliminary results. Without the remainder of the data, which is to be collected, we have only the ability to report trends and observations without the benefit of statistical analysis.

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