Modified Child Seat

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Abstract

We propose a prototype of a gurney-compatible child seat for transporting children (>30kg) in ambulances. Current automobile child seats do not recline; Emergency Medical Technicians (EMTs) must take the child out of the seat and remove the seat from the gurney to lay the child in the supine position for specific medical treatments. However, this procedure takes up valuable time (~3 minutes) and prolongs the time it takes to reach the hospital. In addition, if the child needs to be placed in the supine position, the child will be directly placed in a gurney; as a result, the child is at a greater risk of sustaining an injury in the event of an accident. To circumvent these problems, we designed a prototype (modified child seat) that reclines and eliminates the need of removing the child seat from the gurney in order to place the child in the supine position. Specifically, we incorporated four features to an existing car child seat: reclining mechanism, strap anchor, foot rest and back track mechanism. Our prototype can support children (up to 30 kg) of various heights, unlike current car child seats. To determine our design's mechanical strength, we conducted static testing about the reclining mechanism and sliding strap anchor mechanism. Although testing about both components did not yield the desired result, we believe our design is still a great concept for transporting children in ambulances. Small improvements need to be made and dynamic testing needs to be performed on the prototype to further assess mechanical properties of our design.

1. Introduction

Ambulances, although essential for saving lives, are not known for protecting the occupants in the case of a crash. There are roughly 5000 ambulance crashes each year, causing on average one fatality per week and numerous serious injuries daily [1, 5]. Recently, ambulance safety has gained attention mainly due to research conducted by Dr. Nadine Levick, an emergency physician, and Dr. Marilyn Bull, a pediatrician.

In one particular study, Dr. Levick studied a group of 206 patients under the age of 14 who were transported in ambulances in 1999 [1, 5]. Dr. Levick found that 37% of the children were unrestrained or in a person's lap. And more than 50% were on the gurney, of which 10% were not restrained, while others used only one of the two sets of adult straps on the gurney [1, 5].

Clearly, these statistics show the lack of attention child safety has been given over the years. If the majority of children are strapped in improperly on a gurney, children are more likely to sustain severe injuries in the event of an accident. More importantly, Dr. Levick's research highlights the need for improving child safety in ambulances. Recently, more Emergency Medical Technicians (EMTs) are being trained in properly restraining children to prevent injuries in the event of an accident [1, 2]. However, further work needs to be done in order to improve the safety of children in ambulances.

1.1 Background

Based on the recommendations by leading researchers, children (> 30kg) who do not properly fit onto an adult gurney (Figure 1) must be transported in a car child seat that is directly strapped onto a gurney in an ambulance. Further research by Dr. Levick has shown that the upright position (as shown in Figure 1) is the most comfortable for a child in a car child seat, and children facing the rear of an ambulance are also less likely to suffer head injuries in the upright position in the event of an accident [3].

Figure 1: Currently, children are transported in a car child seat that is strapped to a gurney using the gurney (adult) straps.

At present, when a child needs to be transported in an ambulance, he or she is first placed in a child seat and strapped down in the car seat with a harness. Once the child is secured in the car child seat, the seat is then placed onto a gurney and strapped down with two adult straps located on the sides of the gurney as shown in Figure 1.

At times, the child needs to be placed in the supine position (i.e. flat on his/her back), especially if the child is not breathing properly or has low blood pressure due to a severe infection or injury. During such instances, the child is placed directly onto a gurney since existing child seats do not recline [4].

1.2 Current Design Limitations

The current method of transporting children in car child seats in ambulances is only effective for children who do not need to be laid in the supine position while being transported. However, the current method fails when a child needs to be put in the supine position, as the car child seat does not recline and the two adult straps (Figure 1) to which the seat is strapped down further prevent the child seat from reclining. One has to remove the child seat from the gurney in order to lay the child in the supine position. This procedure is time consuming and can take up to three minutes. More importantly, this procedure prolongs the time it takes to reach the hospital, because the ambulance needs to be stopped in order for the Emergency Medical Technicians (EMTs) to remove the seat from the gurney. Furthermore, if the child is in the supine position, the child can only be strapped down by the two adult straps on the gurney that are not designed for children. This type of arrangement poses further risk of injury in the event of an accident, as children secured with adult straps are likely to be thrown off the gurney [4].

In addition, since the current child seat is non-collapsible and space is limited in the back of an ambulance, a car child seat is not carried at all times in most ambulances. If the EMTs do not bring along a child seat to the site of an accident and discover that there is an injured child, they have no choice but to transport the child directly on a gurney. Again, since the adult straps of the gurney are not recommended for children, children are more prone to injury in the event of an accident.

1.3 Design Solution

Based on the findings and observations, we propose a modified child seat design specifically for ambulances, which circumvents current problems. To ascertain whether our modified child seat design is effective for such applications, we constructed the modified child seat and conducted static testing. In this section, we provide an overview of our proposed modified child seat design. The actual dimensions of the prototype and its related components as well as the materials used to fabricate the modified child seat are provided in the Methods section.

1.3.1 Design Overview

Keeping the current child seat and gurney constraints in mind, we incorporated four new features into existing car child seat to overcome the current limitations the car child seats pose. Drastic changes to the car child seat were not made because the overall design of the car seat is not problematic. However, we incorporated the following four features to the car child seat design: reclining mechanism, strap anchor, leg support, and back rest track (Figure 2).

A reclining mechanism was included in the modified child seat that allows the back (Figure 2) of the seat to recline. For reclining the mechanism, a hinge was placed between the back and base of the seat. A passive spring locking mechanism was placed on one side of the hinge, so the modified child seat can be locked in two positions, upright and supine, by simply pulling on a pin (Figure 3). Aluminum sheets were placed on the sides of the modified child seat to provide extra strength**,** so the seat does not collapse in the event of an accident (Figure 3).

Figure 2: Adjustable straps, aluminum piano hinge, and the slide-out foot rest can be seen in this front view of the prototype.

A general strap mechanism (Figure 2) was also added to ensure children of all ages would be able to fit into the modified child seat. One of the problems with car child seat straps is that the straps are very difficult adjust in order to fit children of all ages, masses and heights. It is best to have straps directly above child's shoulders to reduce the risk of an injury. Keeping this in mind, with a general strap mechanism, one can simply adjust the straps by pressing on a spring loaded lever and moving the straps to desired height (Figure 2). Furthermore, it is possible to adjust the straps by adjusting the buckles on the straps (Figure 2).

In addition, a sliding leg support was included for children with low blood pressure. The leg rest that sits under the base of the seat slides in or out depending on whether it is needed or not (Figure 2).

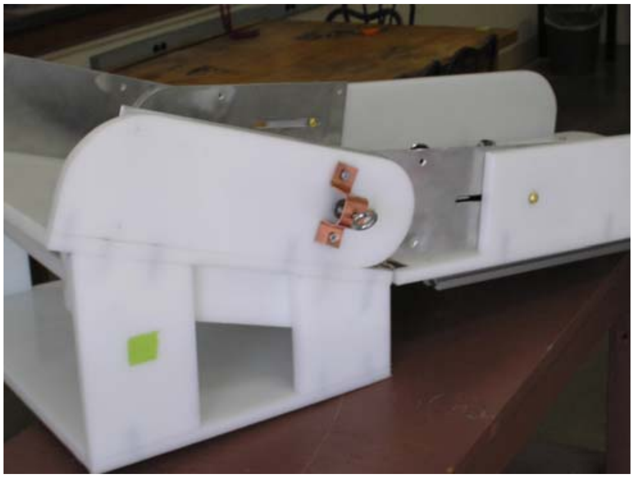

Figure 3: The pin locking mechanism is shown in this side view of the prototype. The back track can be seen under the back rest.

Lastly, a back rest track (Figure 3) was incorporated into the modified child seat. The track consists of two railing on which a slab of High Density Polyethylene (HDPE) slides. The back rest track anchors the back of the seat to the gurney, while allowing the seat to recline with ease. In order for a child car seat to be stable in a crash, it must be anchored not only on its base, but also on its back to prevent movement of the upper part of the seat. A problem is encountered when the seat is reclined. Since the hinge point of the seat is several centimeters above the hinge point of the stretcher, when they are reclined simultaneously, the back of the seat moves relative to the back rest of the stretcher. This prevents the back of the seat from being strapped to the stretcher directly. The back rest track allows parallel movement of the back of the seat with respect to the stretcher while the seat is being reclined.

1.3.2 Design Analysis

When designing the prototype, the forces that would be acting on the seat were analyzed. The benchmark for maximum deceleration during an automobile crash is 20 g (198 m/s^2) **[7].** Automobiles are designed in such a way that the passengers will not be subjected to forces greater than 20 g's. In general, children under 30 kg are transported in car child seats in ambulances [4]. The prototype was designed under the assumption that it was holding the largest child possible, as this scenario would lead to the greatest possible forces being applied to the seat. A mass of 30 kg decelerating at 198 m/s^2 leads to a force of 5940 N. To keep the child secure in the seat, the straps must withstand 5940 N. Since this force is distributed over two straps, each strap must withstand a force of 2970 N.

Using the force of 5940 N acting on the straps, the force acting on the hinge and the pin lock (Figure 4) were calculated using the moment about the hinge. The force acting on the hinge was calculated to be 65.2 kN, and the force acting on the pin was calculated to be 71.2 kN. In this case, the force acting on the back track (Figure 4) was ignored. The calculated values represent the maximum force that could be applied to the hinge and pin when the back track is not secured to the stretcher. Nonetheless, the maximum force acting on the back track was also calculated. This force was calculated under the assumption that the pin was not present. The maximum force to act on the back track was calculated to be 12.1 kN. This value represents the maximum force that would act on the back track if the pin was not in place. In ideal conditions, the pin would be in place, and the back track would be secured to the stretcher, so the actual forces would be less than these calculated forces.

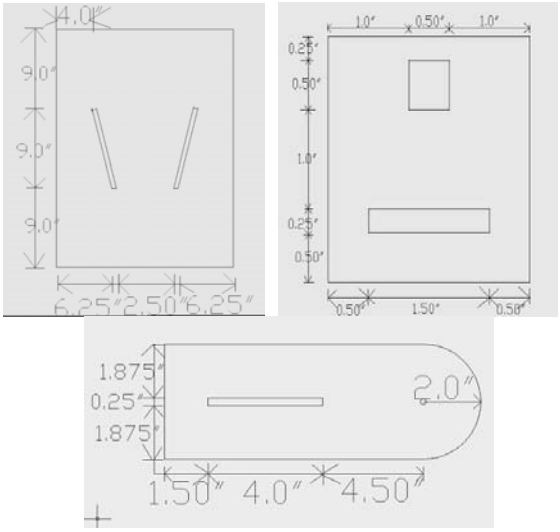

Figure 4: The dimensions of the back rest (top left), aluminum strap anchors, and aluminum hinge pieces (bottom) are shown.

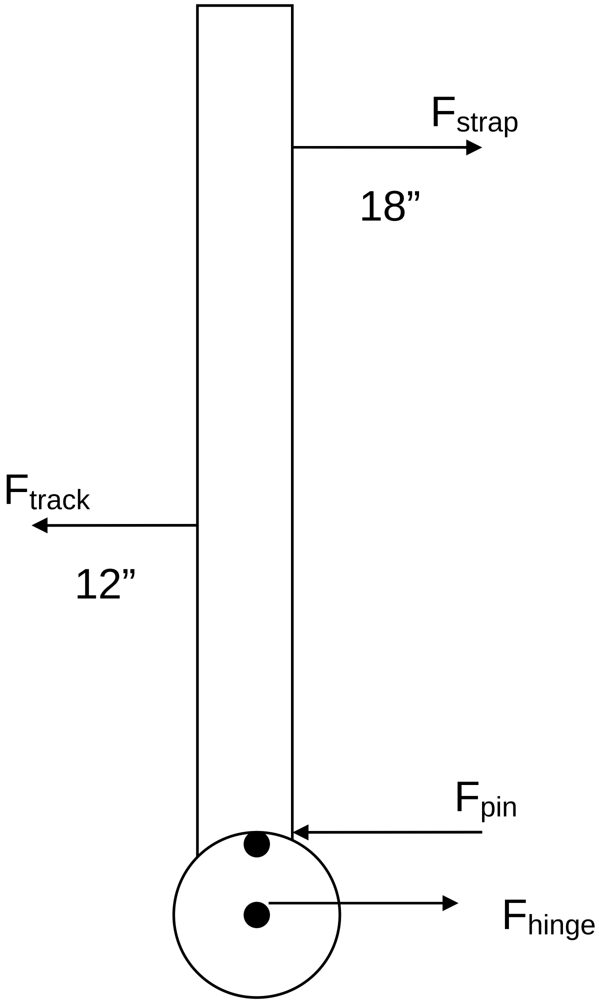

Figure 5: This free body diagram, a side view of the back rest of the seat, was used to calculate the forces acting on the pin, hinge, and back track.

2. Methods

2.1 Fabrication of the modified child seat

Based on the anthropometric data, we specified the dimensions of the modified child seat so children less than 30 kg can fit in the modified child seat [6]. A detailed schematic of the modified child seat with dimensions of each individual component is shown in Figure 5. The modified child seat was fabricated at University of Wisconsin-Madison in Engineering Centers Building.

Similarly, based on the calculated forces, specific materials were chosen for the modified child seat so in the event of accident, the modified child seat does not pose serious risks to the child. All the materials were purchased from McMaster (online) and Home Depot (Madison, WI).

HDPE, 1/2” (1.27 cm) thick, was chosen as the bulk material, because it is strong and has a tensile strength of 4500 psi (31 MPa). Based on the design analysis calculations this material will withstand the required amount of force. In addition, HDPE is a workable material, which was important so that construction would go smoothly. It is also lightweight, compared to metals, and is cost efficient.

Aluminum, with a thickness of 1/8” (0.32 cm), was chosen for the hinge lock mechanism and for the strap anchors. This region of the seat is subject to large forces and high localized pressures. Aluminum Alloy 6061 was used, which was annealed and heat treated for added strength. This metal was also chosen because it is lightweight and easy to work with. The locking pin plays a vital role as it prevents the aluminum sheets and reclining mechanism from collapsing. A 1/4” (0.64 cm) round steel locking pin was chosen, (shear strength of 50000 psi (344 MPa)) that can withstand forces generated in an accident.

2.2 Static Testing

2.2.1 Strap Anchor Test

To ensure that the strap anchors will withstand the calculated maximum forces, a load was directly applied to the straps. A Sintech 10/GL MTS tension/compression machine was used to apply the load (Figure 6). The back rest of the seat was attached to the lower clamp using a strap, and the two child straps were placed in the upper clamp, which was attached to the force transducer. The upper clamp was raised at a constant speed of 0.5 in/s (1.27 cm/s). The load and distance were output every 0.4 s to the computer. There, the data was recorded and plotted using TestWorks software. The load was increased as the upper clamp was raised, until the point of failure was reached.

Figure 6: The testing setup for the strap anchor test is shown. A direct tensile load was applied to the straps.

2.2.2 Hinge Lock Test

To test the pin and hinge lock mechanism, a load was applied to the hinge of the seat. The seat placed in the horizontal position and was raised above the testing table using wood blocks. The base of the seat was supported using a wooden block placed 10” (25.4 cm) from the hinge. The back rest of the seat was supported at a distance of 18” (45.7 cm) from the hinge. A 60,000 lb Southwark tension/compression machine was used to apply a load to the hinge (Figure 7). A steel bar was placed on the hinge to evenly distribute the load across the width of the seat. The head of the compression machine was then lowered onto the steel bar. A load was applied to the seat by manually increasing the load applied by the machine. The load was increased, and the response of the prototype was observed. The load was displayed on a Tate –

Emery load indicator. The load was increased until the seat was observed to be near the point of failure, and the maximum load was recorded.

Figure 7: The setup for the hinge lock test is shown. A load was applied to the hinge to attempt to bend the locked seat.

3. Results

3.1 Strap Anchor Test

The load versus extension plot for the strap anchor test is shown. Failure was reached at a loading of 4697 N. At this point, a weld in the strap locking mechanism failed. The maximum extension was 8.4 cm (Figure 8).

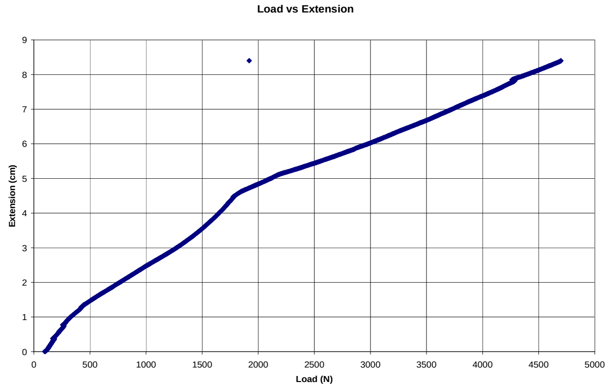

Figure 8: Load vs. extension during the strap anchor test is plotted.

3.2 Hinge Lock Test

In the pin lock test, the seat reached a maximum loading of 778 N. At this point the material was near failure. Bending of the HDPE prevented the load from being increased as high as was necessary. The pin lock was not near failure; it easily withstood the applied force.

4. Discussion

4.1 Strap Anchor Test

The slope of the curve in the load vs. extension plot (Figure 8) corresponds to the rate at which the strap mechanism was extending. The initial rise where the slope is relatively high occurred while the straps were stretching. The stretching of the nylon straps was responsible for the extension under the loading of up to 500 N. After that, most of the extension was due to the bending of the aluminum strap anchors. These were bent significantly during the test (Figure 6**).** They bent the most between 500 N and 1800 N. Above 1800 N, the slope of the curve decreases. As the angle of the aluminum strap anchors approaches the angle of the load being applied, the amount of bending per unit force decreases. This was acceptable, as the aluminum strap anchors were designed to bend but not break. Each child seat is designed to withstand one and only one crash, so deformation of the seat under these forces is acceptable.

Failure under the load of 4697 N fell short of the desired strength of 5940 N. Failure was reached when a weld on the steel T-shaped piece broke. At the maximum loading, all other components being tested did not appear to be near the point of failure. Ideally, the T-shaped piece would be made of solid steel, which would easily withstand the required force. Since we were limited to making only a spot weld, we were not able to apply the desired force to the prototype. However, the prototype withstood nearly the desired amount, and with slight modification could reach the desired loading.

The extension at this point had reached 8.4 cm. This gives an approximation of the distance that a child’s shoulders would travel forward under this loading. Since the straps were not oriented in the same way as they would be on a child, the child’s shoulders would likely move less than this amount.

4.2 Hinge Lock Test

The 778 N applied load to the hinge of the seat led to a shear force of 2723 N on the pin. This did not push the pin to failure. There was significant bending of the HDPE in the base of the seat. If the load would have been increased, the material would have bent further, and may have failed. There were no noticeable effects on the pin. This test showed that the limiting component in bending is most likely the material itself rather than the pin. There would be failure elsewhere in the seat before the pin lock mechanism failed.

Further testing is required to determine the point at which the pin would fail due to forces applied about the hinge. A more complex testing setup with more suitable testing equipment would give a better depiction of how the seat would perform in a crash. Destructive testing would be more suitable for this design, and ideally, crash testing would be performed.

5. Conclusion

Overall, the proposed design is very effective and resolves many of problems that are encountered by EMTs. The four unique features that were incorporated into a child seat provide EMTs, as well children, greater access. Despite the static testing, there are several facets of the design that still need to be studied closely. For example, a rigorous form of dynamic testing is needed to ascertain modified child seat's mechanical properties. Because of the limited equipment and resources, we were only able of conduct static testing on our design. Nonetheless, the static testing results are promising even though several components did not withstand the maximum calculated applied loads. We believe our design will save time as the modified child seat is readily collapsible, non-bulky and user-friendly. In addition, our design will allow EMTs to quickly transfer patients from the gurney to a hospital bed.

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