

## ARTICLE

# Effects and Costs of Requiring Child-Restraint Systems for Young Children Traveling on Commercial Airplanes

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**Context:** The US Federal Aviation Administration is planning a new regulation requiring children younger than 2 years to ride in approved child-restraint seats on airplanes.

**Objectives:** To estimate the annual number of child air crash deaths that might be prevented by the proposed regulation, the threshold proportion of families switching from air to car travel above which the risks of the policy would exceed its benefits, and the cost per death prevented.

**Design:** Risk and economic analyses.

**Results:** Child-restraint seat use could prevent about 0.4 child air crash deaths per year in the United States. Increased deaths as a result of car travel could exceed deaths prevented by restraint seat use if the proportion of fami-

lies switching from air to car travel exceeded about 5% to 10%. The estimate for this proportion varied with assumptions about trip distance, driver characteristics, and the effectiveness of child-restraint seats but is unlikely to exceed 15%. Assuming no increase in car travel, for each dollar increase in the cost of implementing the regulation per round trip per family, the cost per death prevented would increase by about \$6.4 million.

**Conclusions:** Unless space for young children in restraint seats can be provided at low cost to families, with little or no diversion to automobile travel, a policy requiring restraint seat use could cause a net increase in deaths. Even excluding this possibility, the cost of the proposed policy per death prevented is high.

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THE US FEDERAL Aviation Administration (FAA) will soon propose a regulation mandating use of child-restraint systems (CRSs) for all children flying in aircraft.<sup>1</sup> As a consequence, children younger than 2 years would no longer be able to travel on their parents' laps but would require a seat of their own, with the costs passed on to their parents, other passengers, or the airlines' shareholders. This proposed regulation represents a policy change on the part of the FAA, which argued in a 1995 report to Congress that CRSs on aircraft would prevent a maximum of 5 child plane crash deaths per 10 years and would result in a net increase of 82 deaths per 10 years because of families shifting to other, less safe modes of travel.<sup>1,2</sup>

The FAA's 1995 analysis was not accepted by the US National Transportation Safety Board, which argued that the FAA's estimates of diversion of travel from airplanes to cars were too high.<sup>1,3</sup> Since their 2000 meeting, a regulation mandating CRS use for young children on air-

planes has been on the National Transportation Safety Board's list of "Most Wanted Transportation Safety Improvements."<sup>1</sup> Recently, the American Academy of Pediatrics Committee on Injury and Poison Prevention released a policy statement recommending a federal requirement for CRS use on airplanes for all children younger than 2 years.<sup>4</sup> The American

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Academy of Pediatrics committee acknowledged the FAA's previous concern that parents might opt to drive rather than pay for tickets for their young children but dismissed this possibility, stating "no data support this argument."<sup>4</sup> The committee also did not present any analyses of the numbers of lives that might be saved by the policy or the policy's costs.

Because we disagree with the American Academy of Pediatrics committee's assertion that no data support the FAA's concern about travel substitution<sup>2,5</sup> and believe

that analyses of benefits and costs can inform policy decisions like this one, we estimated the possible benefits, risks, and costs of the proposed policy by using a range of values for key unknown variables. We were specifically interested in how many young child air crash deaths might be prevented, the threshold proportion of families switching from air to car travel above which the projected harms of the policy would exceed its projected benefits, and how little the extra seats for young children would have to cost for the policy to approach the cost-effectiveness of other available injury prevention interventions.

## METHODS

The key inputs for our calculations, sources, and ranges for sensitivity analyses are summarized in **Table 1**. We obtained the risk of death per 100 million enplanements according to the US National Transportation Safety Board database<sup>7</sup> by averaging data for years 1982 through 2001, the period for which data were available. (An enplanement is defined as “a revenue passenger boarding an aircraft.”<sup>6</sup>) We estimated the total number of enplanements per year at 650 million, the approximate average of the last 5 years. Air travel decreased substantially after September 11, 2001, but was rising steadily before that; we used the average because we have no way of predicting future changes. We used the FAA’s estimate that about 1% of enplanements are by children younger than 2 years for a total of 6.5 million enplanements in that age group.<sup>2</sup>

We estimated in 2 steps the number of deaths of children younger than 2 years that might be prevented by CRS use. First we estimated the proportion of fatalities that occur in survivable crashes. For simplicity, we defined a survivable crash as any crash in which there were survivors. Of the 2784 deaths on US air carriers from 1982 through 2001, 832 (30%) occurred as a result of crashes in which there were survivors,<sup>8</sup> so we used 30% as our estimate. We assumed CRS use would reduce fatalities only for these survivable crashes. We then estimated the number of lives that could be saved by CRS use as a function of 2 relative risks: the risk of death for restrained children younger than 2 years, as compared with that of other passengers, and the risk of death for unrestrained young children, as compared with that for restrained young children. The relative risk for unrestrained young children, as compared with that for other passengers, is thus the product of these 2 relative risks. Because only 1% of enplanements are by children younger than 2 years, we used the risk for all passengers in place of the risk for passengers older than 2 years to simplify calculations.

For our base case estimate, we used 2 sources of data: extrapolations from car crash data and the FAA’s 1995 report to Congress,<sup>2</sup> which included detailed analyses of children in survivable aircraft crashes from 1978 through 1994. In fatal car crashes, restrained infants and toddlers have about 20% to 60% lower risk of death or serious injury than do restrained adults, even when their tendency to ride in the back seat, which is safer, is taken into account.<sup>9,10</sup> The FAA’s analysis used a 50% lower risk of death or serious injury in restrained young children, as compared with that in other passengers.<sup>2</sup> We used a 50% lower risk for restrained young children, as compared with that in other passengers, as our base case, and we varied this between 0.2 and 1.0 in sensitivity analyses. In car crashes, unrestrained young children have about 2 to 3 times the risk of death or serious injury, as compared with that in restrained young children<sup>9,14</sup>; in the FAA analysis of airplane crashes, the risk ratio for unrestrained vs restrained young children was 2.25. We used 2.5 as our base case, varying it in sensitivity analyses from 1.5 to 4.0.

The number of motor vehicle fatalities that might be caused by diversion of travelers from planes to cars depends not only on the proportion of young children whose parents make this decision but also on the average distance they would drive and the average risk per mile driven. On the other hand, fatalities from plane crashes are related to the number of enplanements rather than to the number of miles flown. We estimated that the average net increase in car travel (ie, driving distance to the destination minus driving distance to the airport) per enplanement for families switching from planes to cars would be 300 miles, with a range of 200 to 400 miles for sensitivity analyses. Assuming 2.5 enplanements per round trip, this would translate into 750 miles per round trip, with a range of 500 to 1000 miles for sensitivity analyses.

Because the risk of motor vehicle fatality is provided per 100 million vehicle-miles traveled,<sup>13</sup> we adjusted for ways in which the risk per vehicle-mile traveled by these children and their families might differ from the averages reflected in the statistics. This risk depends on the average vehicle occupancy for these trips, because the higher the occupancy rate the greater the potential number of fatalities per mile traveled. However, the number of fatalities per mile traveled does not increase proportionately to the number of passengers because passengers have lower death rates than drivers do and because death rates per mile traveled also include deaths in nonpassengers (eg, pedestrians).<sup>12</sup> We estimated the average vehicle occupancy for the extra trips at 3 persons, as compared with the national average of 1.6 persons,<sup>13</sup> but adjusted this occupancy downward to 2.4 (ie, only 1.5 rather than 1.9 times the national average) to account for the lower death rates per mile for passengers vs drivers.

In addition to the factors noted, the risk of motor vehicle fatalities depends on risk characteristics of the drivers. Evans et al<sup>12</sup> estimated coefficients by which the average risk can be multiplied to take into account differences in risk of drivers, cars, and types of driving. We used their coefficients and assumed drivers would be about 30 years old (0.7) and not drink any alcohol when driving (0.6). The coefficient for rural interstate driving was 0.53; we used 0.7 to reflect higher than average but not exclusive use of rural interstate highways. The product of these coefficients ( $0.7 \times 0.6 \times 0.7$ ) is 0.3; we used this as our base case, and we used estimates from 0.2 to 1.0 in sensitivity analyses.

We used commercially available software for calculations (Excel 97; Microsoft Corp, Redmond, Wash) and for confirming all calculations and producing sensitivity analysis graphs (DATA 3.5; TreeAge Corp, Williamstown, Mass). We rounded numbers displayed in tables but carried through all calculations with full precision. Cost estimates are based on July 2002 US dollars; comparisons with dollars from other years were adjusted by using the Consumer Price Index.<sup>15</sup> To convert costs per enplanement to costs per round trip, we estimated that the average round trip included 2.5 enplanements, which is equivalent to estimating that 75% of round trips are nonstop and 25% require a single plane change in each direction. Spreadsheets with all calculations, the downloaded FAA crash data, and the decision trees we used are available on request.

## RESULTS

According to our base case assumptions, the estimated number of young child air travel deaths that would be prevented by CRS use is about 0.4 deaths per year. This number could be as low as 0.05 deaths per year if unrestrained young children had only 1.5 times the risk of restrained young children and if restrained young children had only 20% of the risk of all passengers. Alterna-

**Table 1. Inputs for Calculations of Potential Numbers of Deaths Prevented by Reduced Air Fatalities and Caused by Diversion to Ground Travel**

| Variable                                                                                                                          | Base Case Value | Range   | Reference or Source                                                        |
|-----------------------------------------------------------------------------------------------------------------------------------|-----------------|---------|----------------------------------------------------------------------------|
| <b>Air travel</b>                                                                                                                 |                 |         |                                                                            |
| Overall child and adult death rate per 100 million enplanements*                                                                  | 27.7            | NA      | NTSB <sup>7</sup>                                                          |
| No. of enplanements per round trip                                                                                                | 2.5             | NA      | Estimate                                                                   |
| No. of enplanements per year                                                                                                      | 650 000 000     | NA      | NTSB <sup>7</sup>                                                          |
| Percentage of round trips by children younger than 2 years                                                                        | 1.0             | NA      | FAA <sup>2</sup>                                                           |
| Proportion of deaths occurring in survivable crashes                                                                              | 0.3             | NA      | NTSB <sup>8</sup>                                                          |
| Relative risk of death for unrestrained young children in survivable crashes, as compared with risk for restrained young children | 2.5             | 1.5-4.0 | FAA, <sup>2</sup> Berg et al, <sup>9</sup> and Corneli et al <sup>10</sup> |
| Risk of death for restrained young children in survivable crashes, as compared with overall passenger risk                        | 0.5             | 0.2-1.0 | FAA, <sup>2</sup> Berg et al, <sup>9</sup> and Corneli et al <sup>10</sup> |
| <b>Ground travel</b>                                                                                                              |                 |         |                                                                            |
| Average family size traveling, including child                                                                                    | 3               | NA      | Estimate                                                                   |
| Adjusted average family size traveling, including child†                                                                          | 2.4             | NA      | Estimate                                                                   |
| Average US motor vehicle occupancy                                                                                                | 1.6             | NA      | Bureau of Transportation Statistics <sup>11</sup>                          |
| Risk of car death for families with young children, as compared with that for average drivers                                     | 0.3             | 0.2-1.0 | Evans et al <sup>12</sup>                                                  |
| Average motor vehicle death rate per 100 million vehicle-miles traveled                                                           | 1.5             | NA      | US Department of Transportation <sup>13</sup>                              |
| Average net number of miles driven per diverted enplanement                                                                       | 300             | 200-400 | Estimate                                                                   |

Abbreviations: FAA, US Federal Aviation Administration; NA, not applicable; NTSB, US National Transportation Safety Board.

\*An enplanement is defined as "a revenue passenger boarding an aircraft."<sup>6</sup>

†See "Methods" section.

tively, it could be as high as 1.6 deaths per year if unrestrained young children had 4 times the risk of restrained young children and if restrained young children had no lower risk than did other passengers (**Table 2**). In this last case, the risk of death of unrestrained young children would be 4 times the risk of other passengers. Because the risk of death among the 3360 passengers in survivable crashes from 1982 through 2001 was 25%<sup>8</sup> and the risk of death in young children in such crashes cannot exceed 100%, this last relative risk cannot exceed 4.

We estimated the threshold proportion of families switching from air to car travel at which the projected increase in motor vehicle deaths would exceed the projected reduction in plane crash deaths from CRS use. For our base case, this proportion was 5.4%. As the number of miles per enplanement decreases, the safety advantage of air travel compared with that of car travel decreases and the proportion of families that can switch to car travel without causing a net increase in deaths increases. About 13% of families could switch from air to car travel without a net increase in deaths if their average enplanement were for only 200 miles (**Figure 1**). For enplanements for fewer than 135 miles, driving is estimated to be safer. On the other hand, as the number of miles driven per diverted enplanement and the proportion of families choosing to drive increase, we project a small increase in deaths (Figure 1).

The break-even proportion for switching from air to car travel is also sensitive to assumptions about the relative risk of death for the families choosing to drive, particularly as that relative risk declines below the base case estimate of about 0.3. If the motor vehicle death rate per vehicle-mile traveled for families switching from air to car travel were one fifth of the national average (ie, a relative risk of 0.20), about 12% could switch from air to car travel without a net increase in deaths (**Figure 2**). If the risk per vehicle-mile traveled of

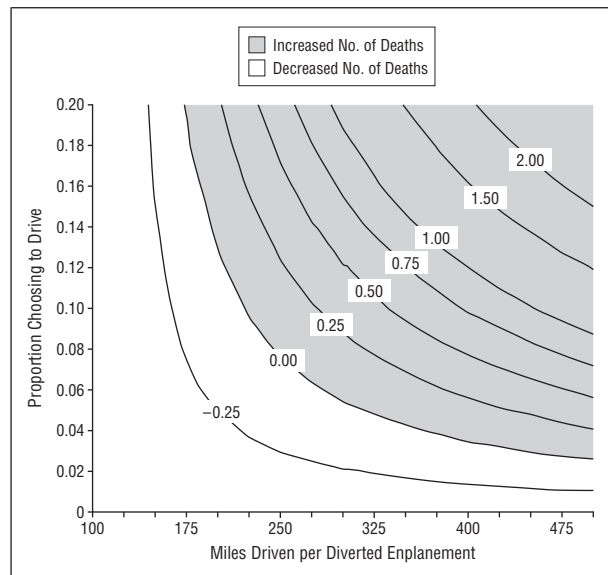
**Table 2. Potential Number of Child Fatalities From US Air Travel Prevented per Year by Use of a Child-Restraint System\***

| Relative Risk for Unrestrained Young Children, as Compared With That for Restrained Young Children | Relative Risk for Restrained Young Children, as Compared With That for All Passengers |      |             |      |      |
|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------|-------------|------|------|
|                                                                                                    | 0.20                                                                                  | 0.35 | 0.50        | 0.75 | 1.00 |
| 1.5                                                                                                | 0.05                                                                                  | 0.09 | 0.14        | 0.20 | 0.27 |
| 2.0                                                                                                | 0.11                                                                                  | 0.19 | 0.27        | 0.41 | 0.54 |
| 2.5                                                                                                | 0.16                                                                                  | 0.28 | <b>0.41</b> | 0.61 | 0.81 |
| 3.0                                                                                                | 0.22                                                                                  | 0.38 | 0.54        | 0.81 | 1.08 |
| 4.0                                                                                                | 0.32                                                                                  | 0.57 | 0.81        | 1.22 | 1.62 |

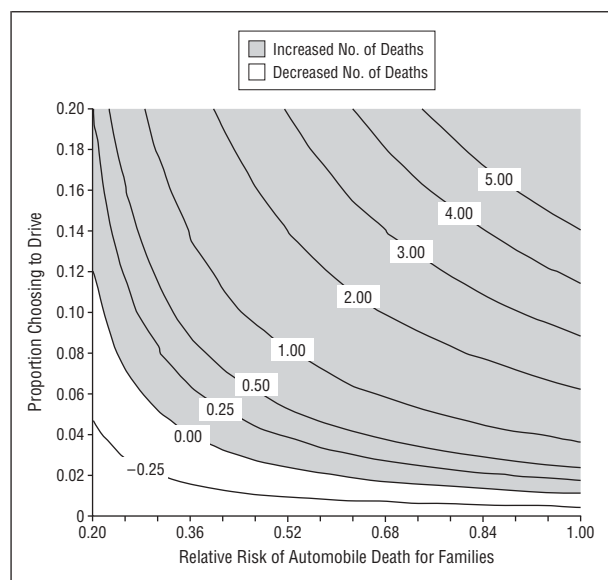
\*Assumes 6.5 million young child enplanements (defined as "revenue passenger boarding an aircraft"<sup>6</sup>) per year, 27.7 total deaths per 100 million enplanements, and 30% of deaths occurring in survivable crashes. The relative risk for restrained young children, as compared with that for all passengers is the product of the row and column headings. Base case value is in boldface.

families switching to car travel were the same as the national average, car deaths caused would exceed air crash deaths prevented if only about 1% of families chose to drive (Figure 2).

Because the policy would lead to a net increase in deaths if more than about 5% to 10% of families switched from air to car travel, we assumed that no families would switch when we calculated the cost of the policy per round trip per death prevented. The cost per year is simply the number of enplanements by young children per year (about 6.5 million) times the cost per round trip divided by 2.5 (the estimated number of enplanements per round trip). To calculate the cost per death prevented, we divide this cost by the number of deaths prevented per year (0.4). Thus, ignoring the possibility of increased deaths due to diversion to car travel, the base case estimate for cost of mandatory CRS use is about \$6.4 mil-



**Figure 1.** Net effect of mandated child-restraint system use as a function of the proportion of families who choose to drive rather than fly and the average number of miles driven per diverted enplanement. The labeled isocontour lines show the specified net change in the annual number of deaths.



**Figure 2.** Net effect of mandated child-restraint system use as a function of the proportion of families who choose to drive rather than fly and the relative risk of automotive fatality for families choosing to drive, as compared with that of average drivers. The labeled isocontour lines show the specified net change in the annual number of deaths.

lion per death prevented for each dollar cost of the policy per round trip per young child (**Table 3**). For example, if the additional cost per round trip were \$200 per young child, the cost per death prevented, ignoring car crash deaths, would be about \$1.3 billion.

To obtain the estimated cost per life-year saved, we assumed a 75-year additional life expectancy and 3% discounting, so the cost per death prevented can be divided by 30. That is, the cost per discounted life-year is about \$214 000 for each dollar cost per round trip per young child. Thus, if the average round-trip cost per young

**Table 3. Cost of Mandatory Child-Restraint System Use Policy per Life Saved and per Life-Year Saved, Assuming No Increase in Deaths From Ground Travel**

| Cost per Round Trip, \$ | Cost per Life Saved,* \$ | Cost per Life-Year Saved (3% Discounting),† \$ |
|-------------------------|--------------------------|------------------------------------------------|
| 200.00                  | 1 283 594 063            | 42 786 469                                     |
| 100.00                  | 641 797 032              | 21 393 234                                     |
| 50.00                   | 320 898 516              | 10 696 617                                     |
| 20.00                   | 128 359 406              | 4 278 647                                      |
| 10.00                   | 64 179 703               | 2 139 323                                      |
| 5.00                    | 32 089 852               | 1 069 662                                      |
| 1.00                    | 6 417 970                | 213 932                                        |
| 0.25                    | 1 604 493                | 53 483                                         |

\*Lives saved by families forgoing travel altogether are not included. Assumes 0.4 lives saved per 6.5 million child enplanements (defined as "a revenue passenger boarding an aircraft"<sup>10</sup>) and 2.5 enplanements per round trip.

†Based on life expectancy of 75 years, which is equivalent to 30 years with 3% discounting.

child were \$200, the cost per discounted life-year saved would be about \$43 million. Put another way, for the cost per discounted life-year to be in the range of \$50 000, the cost of complying with the regulation in our base case would need to be about \$0.25 per round trip per young child and there could be no diversion to cars. These costs can easily be adjusted to account for different assumptions about the possible number of young child air crash deaths prevented per year. For example, at the extreme of the sensitivity analysis, where the number of lives saved by requiring CRS use is 1.6 per year and there is no increase in deaths from motor vehicle crashes, the cost per life-year saved would be about \$53 000 for each dollar cost per round trip per young child.

#### COMMENT

Using available data on the risk of fatalities from air travel and the survivability of crashes and reasonable assumptions for relative risks of death for restrained and unrestrained young children involved in crashes, we found that the number of deaths that could be prevented in the United States with mandatory CRS use in commercial aircraft is small—probably less than 1 and almost certainly less than 2 per year. The number of deaths that could be prevented by mandatory CRS use is limited because the number of deaths of unrestrained young children in survivable crashes is already low.

Because of the small projected absolute benefit of the policy, it is important to examine its risks—not because the risks are large but because they could be small and still exceed the projected benefits. We found that a policy of requiring CRS use for airplane travel is likely to lead to a net increase in deaths caused by increased motor vehicle travel if the proportion of families switching to automobile travel exceeds about 5% to 10%. This threshold varied with the estimated number of lives saved by CRS use on airplanes, the average length of the added round trips by car, and the risk profile of the drivers but is unlikely to exceed 15%.

The small magnitude of potential benefit per young child also makes the cost per life saved high unless the

cost per round trip per young child is close to zero. Even if the policy led to no increase in car travel and cost only \$20 per round trip per young child, the cost per life saved would be about \$4.3 million per discounted life-year. After we adjusted the cost-effectiveness estimates in a review by Tengs et al<sup>16</sup> upward to 2002 dollars, the cost is still more than 33 000 times the cost per life-year of mandatory seat belts and child restraints for cars and more than 60 times the median cost per life-year saved of 132 other fatal-injury prevention interventions.

Our estimates for young child deaths that might be prevented by CRS use are based partly on extrapolations from car crash data. Unlike car crashes, in survivable airplane crashes, only about 60% of deaths are caused by the impact<sup>17</sup>; most of the remainder are caused by heat, smoke, and toxic fumes. Use of CRSs presumably would provide less protection from some of these injuries than from injuries related to impact. On the other hand, in at least 1 widely publicized crash, lack of a CRS might have interfered with locating and evacuating a young child.<sup>18</sup> Because of lack of data for airplane crashes and these 2 differences from car crashes acting in opposite directions, we extrapolated from car crash data and acknowledged uncertainties in sensitivity analyses.

Our results for possibly preventable young child air crash deaths are in general agreement with those of others who have examined these data. Our base case estimate of about 0.4 air crash deaths per year prevented by CRS use is virtually the same as the FAA's estimate of 5 deaths in 10 years. Fife et al<sup>19</sup> also estimated about 0.6 lives per year could be saved by CRS use. Their estimate for the relative risk for unrestrained young children, as compared with that for adults, was about 6, which is higher than ours, but they excluded crashes in which injuries were not caused by deceleration or in which all deaths occurred in compartments with no survivors. In addition, their analysis was based on only 5 young child deaths in 14 crashes from 1976 through 1979.

The number of additional deaths due to car travel depends largely on the proportion of families choosing to drive rather than fly, which we did not attempt to estimate in this study. The FAA used economic modeling to estimate that about 20% of families would opt for car rather than air travel.<sup>2</sup> Their model was more comprehensive than the one reported here because it took into account other modes of ground travel besides cars and the likelihood that, depending on the distance of the trip and the increase in the fare, many families would forgo travel entirely, which would lead to a small reduction in air fatalities in older passengers and in children.

Although full details of the calculations are not provided, the reason that the FAA estimate of a net increase of 8.2 deaths per year is higher than ours appears to be primarily because of higher estimates for the number of families choosing to drive and a smaller downward adjustment in the risk per mile driven.<sup>2</sup> McKenzie and Lee<sup>20</sup> estimated an increase of 5 deaths and 175 disabling injuries per year from car travel as a result of mandatory CRS use—a number higher than ours, probably for the same reasons. Our model shows results similar to those of the FAA<sup>2</sup> and McKenzie and Lee<sup>20</sup> if the proportion of

families choosing to drive is about 20% and the relative risk of death from these car crashes is about the national average (Figure 2).

There are many factors we did not consider in this analysis. We did not consider possible benefits of CRS use in reducing nonfatal injuries. However, the net number of serious nonfatal injuries prevented is likely to be small because serious nonfatal injuries from air travel are less common than are fatalities.<sup>2,7</sup> In contrast, serious nonfatal injuries from motor vehicle travel are about 80 times as common as are fatalities.<sup>13</sup> Thus, the reduction of nonfatal injuries from CRS use is likely to be small, and the possible increase from diversion to car travel would be much larger. We also did not consider a variety of other outcomes that might be affected by a policy of mandatory CRS use. These outcomes include convenience of families and comfort of young children and of surrounding passengers, which could be enhanced by the extra room available for the child in a CRS or diminished if children were kept in CRSs when they wanted to be held or breastfed. Other possible benefits of CRS use we did not consider include decreased anxiety of parents and airline personnel and reduction of injuries to young children during turbulence and to surrounding passengers from unrestrained young children during crashes.

Our cost estimates were all expressed as cost per round trip per child. The main cost would be the cost of a ticket, but there would also be the cost of buying a CRS approved for airplane use and additional costs to airlines and inconvenience to passengers of ensuring adherence to the rule. For example, airlines would need to ensure that the model of safety seat brought by parents was approved for air travel and would need a supply of approved safety seats to loan or rent to passengers who arrive at the airport without an approved seat.

We also did not estimate costs and benefits of alternatives to mandatory CRS use on aircraft. One scenario modeled by the FAA and found far superior to mandatory CRS use<sup>2(p2-10)</sup> is to allow a family member to reserve an adjacent seat for a young child's use on a space-available basis. If this were done, except when flights were full, parents could put their child in a CRS in the seat next to them, without needing to buy a ticket and without revenue loss to the airline. An approach that might reduce injuries due to turbulence is a safety harness that attaches to the parent's seat belt. However, because of the risk to the child of being crushed between the adult and the seat in front in the event of a crash, these harnesses are not approved by the FAA for use during takeoff and landing.

Additional research could allow us to estimate some of the parameters of our model with greater confidence. Such parameters include the average family size and average number of enplanements per round trip of families traveling with young children, the performance of different brands of CRSs in airplane crash simulations, and the average net number of vehicle-miles that families electing to drive rather than fly would travel. In addition, families could be surveyed about the price sensitivity of their decision to drive rather than to buy a ticket for their child. The trouble with this last approach, however, is that the answers to such questions on a survey

## What This Study Adds

Unrestrained children younger than 2 years have died in potentially survivable airplane crashes. However, the effects, costs, and risks of attempting to prevent such deaths by requiring CRSs for all children flying on airplanes are not known.

Results of this study show that requiring CRSs on airplanes would prevent few airplane crash deaths and might cause an increase in motor vehicle deaths if many families switched to travel by car rather than paying additional fares for their young children. Irrespective of that possibility, the cost of the regulation per death prevented would be high—about \$1.3 billion if the price of the round-trip ticket for the young child were \$200. These findings suggest that a policy requiring CRSs on airplanes would be a poor use of societal resources.

might not match what people actually would do, and the answers would probably strongly depend on whether and how the projected benefits of CRS use were quantified for parents. We do not advocate additional research into any of these areas because we believe the probability that the results would substantively affect the lopsided cost-benefit balance of a mandatory CRS policy is close to zero.

We conclude that a policy of requiring CRS use on aircraft is likely to lead to a small net increase in deaths and injuries unless the cost of complying with the policy is low enough that fewer than 5% to 10% of families with young children switch from air to car travel. Even if young children in CRSs were allowed to fly at no cost to their families, the associated societal cost would need to be less than \$1 per child per round trip for the cost-effectiveness of CRS use on aircraft to approach that of other available injury prevention interventions.

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## REFERENCES

1. Federal Aviation Administration National Aviation Safety Data Analysis Center. NTSB safety recommendations to the FAA with FAA responses database recommendation A-95-51. Available at: <http://www.nasdac.faa.gov>. Accessed March 12, 2002.
2. Federal Aviation Administration. *Report to Congress: Child Restraint Systems: Report of the Secretary of Transportation to the United States Congress Pursuant to Section 522 of the Federal Aviation Administration Authorization Act of 1994, Pub L No. 103-305*. Washington, DC: US Dept of Transportation; 1995.
3. Sweedler B. Testimony of Barry Sweedler, Director, Office of Safety Recommendations, National Transportation Safety Board, before the Committee on Transportation and Infrastructure Subcommittee on Aviation, House of Representatives, regarding legislation to require the use of child safety restraint systems aboard aircraft. August 1, 1996. Available at: <http://www.ntsb.gov/speeches/S960801.htm>. Accessed March 12, 2002.
4. American Academy of Pediatrics Committee on Injury and Poison Prevention. Restraint use on aircraft. *Pediatrics*. 2001;108:1218-1222.
5. Anderson PL, McLellan RD, Overton JP, Wolfram GL. Price elasticity of demand. Available at: <http://www.mackinac.org/1247>. Accessed March 13, 2003.
6. Air Transport Association. Economics glossary: common aviation terms and references. Available at: <http://www.airlines.org/public/industry/display1.asp?nid=5244>. Accessed July 23, 2001.
7. US National Transportation Safety Board. Table 3: passenger injuries and injury rates, 1983 through 2002, for US air carriers operating under 14 CFR 121. Available at: <http://www.ntsb.gov/aviation/Table3.htm>. Accessed April 14, 2002.
8. US National Transportation Safety Board. Accidents involving passenger fatalities US airlines (part 121), 1982 - present. March 2002. Available at: <http://www.ntsb.gov/aviation/Paxfatal.htm>. Accessed April 15, 2002.
9. Berg MD, Cook L, Corneli HM, Vernon DD, Dean JM. Effect of seating position and restraint use on injuries to children in motor vehicle crashes. *Pediatrics*. 2000; 105:831-835.
10. Corneli HM, Cook LJ, Dean JM. Adults and children in severe motor vehicle crashes: a matched-pairs study. *Ann Emerg Med*. 2000;36:340-345.
11. Bureau of Transportation Statistics. National transportation statistics 2000. Available at: <http://www.bts.gov/publications/nts/2000/index.html>. Accessed March 20, 2002.
12. Evans L, Frick MC, Schwing RC. Is it safer to fly or drive? *Risk Anal*. 1990;10: 239-246.
13. US Department of Transportation National Highway Traffic Safety Administration. *Traffic Safety Facts 1999: A Compilation of Motor Vehicle Crash Data From the Fatality Analysis Reporting System and the General Estimates System*. Washington, DC: US Dept of Transportation, National Highway Traffic Safety Administration; 2000:15.
14. Johnston C, Rivara FP, Soderberg R. Children in car crashes: analysis of data for injury and use of restraints. *Pediatrics*. 1994;93:960-965.
15. US Department of Labor, Bureau of Labor Statistics. Consumer Price Index, all urban consumers (CPI-U). Available at: <ftp://ftp.bls.gov/pub/special.requests/cpi/cpiat.txt>. Accessed September 6, 2002.
16. Tengs TO, Adams ME, Pliskin JS, et al. Five-hundred life-saving interventions and their cost-effectiveness. *Risk Anal*. 1995;15:369-390.
17. European Transport Safety Council. Increasing the survival rate in aircraft accidents: impact protection, fire survivability and evacuation. Available at: [http://www.etsc.be/rep\\_air2.htm](http://www.etsc.be/rep_air2.htm). Accessed April 1, 2003.
18. Brown-Lohr J. Testimony before the US House of Representatives Subcommittee on Aviation: hearing on HR 1309: child safety restraint systems requirement on commercial aircraft. Available at: [http://commdocs.house.gov/committees/Trans/hpw104-63.000/hpw104-63\\_0.htm](http://commdocs.house.gov/committees/Trans/hpw104-63.000/hpw104-63_0.htm). Accessed April 1, 2003.
19. Fife D, Rosner B, McKibben W. Relative mortality of unbelted infant passengers and belted non-infant passengers in air accidents with survivors. *Am J Public Health*. 1981;71:1242-1246.
20. McKenzie RB, Lee DR. Ending the free airplane rides of infants: a myopic method of saving lives: CATO Institute Briefing Paper, No. 11. Available at: <http://www.cato.org/pubs/briefs/bp-011.html>. Accessed April 15, 2002.