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## Cost comparison of mechanically ventilated patients across the age span

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### Abstract

**Objective**—to compare use of mechanical ventilation and hospital costs across ventilated patients of all ages, preterm through adults, in a nationally-representative sample.

**Study Design**—secondary analysis of the 2009 Agency for Healthcare Research and Quality National Inpatient Sample.

**Results**—1,107,563 (2.8%) patients received mechanical ventilation. For surviving ventilated patients, median costs for infants < 32 weeks' gestation were \$51,000–\$209,000, whereas median costs for older patients were lower, from \$17,000–\$25,000. For non-surviving ventilated patients, median costs were \$27,000–\$39,000 except at the extremes of age; the median cost was \$10,000 for <24 week newborns, and \$14,000 for 91+ year adults. Newborns of all gestational ages had a disproportionate share of hospital costs relative to their total volume.

**Conclusions**—Most ICU resources at the extremes of age are not directed toward non-surviving patients. From a perinatal perspective, attention should be directed toward improving outcomes and reducing costs for all infants, not just at the earliest gestational ages.

### Keywords

premature infant; respiratory insufficiency; artificial respiration; hospital costs; critical care; neonatology

### Introduction

Intensive care is expensive. In 2005, critical care medicine represented 4% of all national health expenditures and 13.4% of hospital costs.<sup>(1, 2)</sup> Although health care is not deliberately rationed in the U.S., the cost and resource intensity of intensive care leads to

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ongoing debate about how to distribute it. This debate plays out differently across the age spectrum: for older children and adults, debate takes the form of allocation decisions for limited ICU beds or nursing staffing ratios to more and less critically ill patients.(3–7) For premature neonates, resource allocation and quality of life discussions center around gestational-age-based discretionary resuscitation guidelines.(8–11)

A 1997 single-center study comparing neonatal and adult ICU costs found that 8% of neonatal ICU days were allocated to non-survivors, compared with 29% of adult intensive care unit days.(9) This analysis suggests efficient resource use within NICUs relative to adult ICUs, and has been cited in consensus guidelines and debates about resuscitation of extremely preterm infants.(7, 12–18) Since 1997, there have been several changes in ICU care for both neonates and adults. Surviving preterm neonates are treated less frequently with mechanical ventilation, which may decrease costs of care.(19) For adults, clinical advances have improved survival for critical illnesses requiring mechanical ventilation, such as severe sepsis.(20, 21) There has also been more attention to end-of-life decision-making in ICUs, with the Choosing Wisely initiative encouraging conversations about avoiding prolonged life-sustaining therapies in high-risk patients.(22) As a result, the comparison of costs of care for patients of different ages may be different in contemporary ICUs.

The goals of this study were to develop national estimates of the use of mechanical ventilation across all age groups, preterm neonates through adults, and to compare hospital costs for surviving and non-surviving patients receiving mechanical ventilation in each age group. This would provide a contemporary national reference of the costs of mechanical ventilation for extremely preterm infants, and in turn inform the ongoing debate about allocation of intensive care resources for the sickest hospitalized patients across the age spectrum.

## Materials and Methods

We performed a secondary analysis of the 2009 Agency for Healthcare Research and Quality (AHRQ) National Inpatient Sample, which is the largest all-payer database of inpatient care in the United States.(23) Each hospitalization is listed as an individual entry, and includes up to 25 diagnoses and 15 procedures as classified by International Classification of Diseases, 9<sup>th</sup> Revision, Clinical Modification (ICD-9-CM) codes.(24) The dataset contains administrative data on a 20% sample of discharges from all community hospitals in the U.S. excluding rehabilitation and long-term acute care hospitals, and covers patients of all insurance types. The sampling is stratified by urban versus rural, teaching versus non-teaching, and regions of the country; associated sampling weights allow analysis of nationally representative estimates.(23)

### Study population and variable definitions

Our predictor variable of interest was age at admission. Patients younger than one year of age were classified based on admission day of life. Newborns admitted on day of life 0 or 1 were divided into gestational age groups, as identified by ICD-9 diagnosis codes 765.21–765.29: <24 weeks, 24 weeks, 25–28 weeks, 29–32 weeks, 33–36 weeks, and 37+ weeks' gestation. Infants who were admitted after day of life 1 were classified as preterm

(gestational age <37 weeks) or term (gestational age 37+ weeks), and considered as a separate category from newborns because their shorter length of stay would complicate our goal of hospital cost comparisons. We defined patients 1 year of age and older in groups by year: 1–17, 18–40, 41–50, 51–60, 61–70, 71–80, 81–90, and 91+.

The primary study outcomes were cost of hospitalization for surviving and non-surviving patients in 2009 U.S. dollars, which were calculated by converting charges using Medicare cost-charge ratios. A secondary analysis included a variable for discharge to hospice care.

We identified all patients who had received mechanical ventilation, as coded by ICD-9 procedure codes 96.70–96.72. No variable for ICU admission was available in this dataset. We included hospital descriptors used to define sampling strata including geographic region, location, teaching status, ownership and bed size as categorized in the database.

Because our study goal was to compare costs, which are closely related to length of stay, we excluded patients who were transferred prior to discharge. After identifying rates of missing data, we excluded patients with missing age or discharge status. For premature newborns, we excluded any patients with multiple discrepant gestational age codes.

### Statistical analysis

We used the survey weights for discharge and cost to generate national estimates of patient volumes and hospitalization costs in each age group. We identified the proportion of patients receiving mechanical ventilation in each age group, as well as the use of mechanical ventilation among surviving and non-surviving patients. For patients receiving mechanical ventilation, we compared each age group's mortality before hospital discharge and the median cost of hospitalization for surviving and non-surviving patients. Finally, we compared the total cost of hospitalization for surviving and non-surviving patients in each age group. We compared differences in proportions by chi-squared tests, and differences between medians using Kruskal-Wallis tests. For multiple comparisons of medians, Dunn's multiple comparison adjustment was used following a global Kruskal-Wallis test, to provide a conservative non-parametric equivalent to a Bonferroni adjustment. Statistical significance was defined as  $p < 0.05$ . Stata 13.0 was used for all analyses.

## Results

The 2009 National Inpatient Sample contains data on 7,810,762 hospitalizations sampled from 1050 hospitals; hospitals were sampled in 60 strata grouped by geographic region, hospital bed size, urban versus rural environment, and teaching versus non-teaching hospital. Using this data and associated sampling weights, an estimated 39,434,956 hospitalizations occurred in 2009, of which 1,107,563 (2.8%) used mechanical ventilation. Rates of mechanical ventilation varied from 0.7–4.5% (chi-squared  $p < 0.001$ ) across the sampling strata used in the National Inpatient Sample.

### Use of Mechanical Ventilation By Age Group

Figure 1a shows differences in use of mechanical ventilation across age groups. Overall, preterm newborns were much more likely to receive mechanical ventilation during a hospital

stay than any other age group ( $p < 0.001$ ). Figure 1b shows the differences in mechanical ventilation among surviving and non-surviving patients. Among patients who survived to hospital discharge, there was a decrease in the use of mechanical ventilation at progressively later gestational ages, from >90% of surviving newborns <24 weeks' gestation through <1% of surviving term newborns through adults (Figure 1b). Among non-surviving patients, however, there was far less frequent use of mechanical ventilation at the extremes of age. Only 17% of non-surviving infants <24 weeks' gestation received mechanical ventilation, lower than all other age groups except adults >90 years old. In contrast, more than 50% of non-surviving patients received mechanical ventilation in the age range spanning newborn infants 24 weeks' gestation through adults 51–60 years old.

### **Mortality among patients receiving mechanical ventilation**

Figure 2 shows a U-shaped pattern of mortality by age among patients receiving mechanical ventilation. 66% of ventilated newborns <24 weeks' gestation died before hospital discharge, similar to ventilated adults 71–80 years old. 44% of ventilated newborns 24 weeks' gestation died before hospital discharge, similar to ventilated adults 51–60 years old. 21% of ventilated newborns 25–28 weeks' gestation died before hospital discharge, similar to ventilated term infants and children 1–17 years old. Ventilated preterm newborns 29–36 weeks' gestation had the lowest mortality of all age groups, at 5%. Adults had steadily increasing mortality at progressively older ages, from 21% of ventilated adults 18–40 years old to 83% of ventilated adults 91+ years old. A secondary analysis including a variable for discharge with hospice care did not alter these results.

### **Cost of hospitalization for patients receiving mechanical ventilation**

Figure 3a shows the median hospital costs for surviving and non-surviving patients in each age group. Surviving preterm newborns had higher median hospital costs at earlier gestational ages, from \$209,000 for surviving ventilated infants <24 weeks' gestation to \$51,000 for surviving ventilated infants 29–32 weeks' gestation. Surviving ventilated newborns 33 weeks' gestation and later, children and adults all had similar hospital costs between \$17,000–25,000. Among non-surviving ventilated patients, term newborns, children, and infants transferred after day of life 1 had the highest median hospital costs of all age groups, from \$27,000–\$39,000. Hospital costs for non-surviving patients were lowest at the extremes of age; the median hospital cost for a non-surviving ventilated <24 week newborn was \$10,000, and for a non-surviving ventilated 91+ year adult was \$14,000 (Dunn's multiple comparison adjustment was  $p < 0.001$  for each pairwise cost comparison between <24 week newborns and 91+ year adults versus each other age group, following a global Kruskal-Wallis test).

Figure 3b compares the total cost of care for surviving versus non-surviving patients. More than 80% of dollars for all infants and children were spent on surviving patients, except for those born <24 weeks' gestation. Although newborns <24 weeks' gestation had the lowest proportion of dollars spent on surviving patients (among infants and children), at 78%, that proportion was still higher than all ventilated adult patients. With increasing age, ventilated adult patients had a decreasing proportion of dollars spent on survivors.

### Relative proportions of hospital discharges versus total costs

Figure 4 compares each age group's proportion of hospital costs versus patient volume among the subset of patients receiving mechanical ventilation. Overall, patients at the extremes of age were both lowest in number and lowest in total costs. Ventilated preterm newborns made up a small proportion of both total volume and costs for ventilated patients. However, newborn age groups >24 weeks' gestation through full term had a disproportionate share of total hospital costs relative to their total volume. Ventilated adults, who made up the majority of both patient volume and hospital costs, had a lower proportion of costs relative to their patient volume at all age groups.

### Discussion

This study is the first to compare use of mechanical ventilation and costs of hospitalization across ventilated patients of all ages in a contemporary nationally-representative sample of hospital admissions in the United States. We draw the following main conclusions:

1. Although surviving preterm newborns are more likely to receive mechanical ventilation during their hospitalization than all other age groups, non-surviving patients at both extremes of age are less likely to receive mechanical ventilation than all other age groups.
2. Most hospital dollars for ventilated infants were spent on surviving infants, including at the earliest gestational ages. This is both because non-surviving preterm infants do not have higher costs than any other age group, and because surviving preterm infants' hospital stays cost more than other age groups.
3. Compared to adult patients, infants constitute a relatively small proportion of ventilated patients and hospital costs in the U.S. Infants born after the discretionary resuscitation window of 24 weeks' gestation generate a disproportionate share of costs relative to their total numbers of hospitalized patients.

This is the first national estimate of the use of mechanical ventilation for surviving and non-surviving patients across age groups including preterm infants through adults. We found that non-surviving patients at the extremes of age were far less likely to receive mechanical ventilation than all other age groups. This is consistent with gestational age-based discretionary resuscitation policies for newborns <24 weeks' old, and with increasing efforts toward advanced care planning for elderly patients. It is also consistent with survey studies showing that respondents are willing to forego resuscitation for the very young and very old. (25–28) Whether the observed difference in mechanical ventilation for non-surviving patients reflects informed discussions with families is beyond the scope of this study, and an opportunity for further research. Rates of mechanical ventilation for surviving preterm 24 weeks' gestation in this study and mortality among ventilated preterm infants were both consistent with reports from the NICHD Neonatal Research Network,(29) suggesting reasonable capture of mechanical ventilation by ICD-9 codes. Given the significant healthcare provider distress that occurs around a perceived inappropriate provision of ICU resources at the extremes of age,(8) these data should provide reassurance that on a

population level, most ICU resources at the extremes of age are not directed toward non-surviving patients.

High hospital costs for preterm newborns have been described, (9, 30) but few reports have compared costs of care across age groups. When examining the total hospital costs of ventilated patients in a single-center study, Meadow et al. noted >80% of dollars for ventilated preterm infants and children were spent on surviving patients. Our findings provide a nationally-representative contemporary confirmation that ICU resources are not “wasted” on non-surviving preterm infants. Compared to adults of all age groups, costs of mechanical ventilation for infants and children are far more likely to be directed toward survivors, even when infants <24 weeks’ gestation are considered. These findings do not suggest that hospitalization of extremely preterm newborns is a bargain. There is a 10-fold difference in median cost of hospitalization between a surviving ventilated newborn 24 weeks’ gestation and a surviving ventilated adult. Unlike other patients in the hospital, who can be prepared for discharge home once an acute illness resolves, even relatively healthy preterm infants must remain in the hospital until near corrected term gestational age. For this reason, it may be unrealistic to reduce some of the costs of preterm newborn care. However, the disproportionate hospital costs incurred by preterm infants of all gestational ages calls for more attention to drivers of long hospitalizations in this population. There is known practice variation between U.S. NICUs which affects length of stay, including management of apnea of prematurity and bronchopulmonary dysplasia.(31–34) Research to address the safety, cost, and post-discharge outcomes of these practices will be a critical first step in addressing whether shortening length of stay is a reasonable goal for optimal patient outcomes.

Children are generally healthy, and sick premature infants are relatively few in number. Although mechanical ventilation for critically ill infants and children tends to be less controversial than resuscitation of extremely preterm infants,(14, 26, 28, 35) the relative cost of mechanical ventilation for these patients is greater, and more resources are devoted to non-survivors in this population. This likely reflects a wider range of disease processes that might require mechanical ventilation, such as sepsis and congenital anomalies, which are known to incur high mortality.(36–38) Extremely preterm infants are a more frequently studied group with regard to mortality and hospital costs than term infants and children, in part due to the heterogeneous nature of the latter groups. But since older infants and children contribute more to the overall cost of health care than preterm infants, and more dollars are spent on non-survivors, critical evaluation of delivery of intensive care for this population is needed.

This study has several limitations. The de-identified hospitalization entries were not linked by a patient identification number, such that we were not able to identify re-admissions by a single patient. Transferred patients were excluded from this analysis since information on costs and mortality would not be comparable to other patients, and we do not have information about reasons for their transfer. Although we had very few unknown or discrepant ICD-9 codes for gestational age in newborns, and ICD-9 coding for procedures such as mechanical ventilation have been shown to be reliable, ICD-9 codes lack important prognostic factors for preterm infants such as birth weight and receipt of antenatal steroids.

Information on comorbid conditions could have yielded further stratification of costs by patient complexity. There is no ICD-9 code for 23 weeks' gestation; ICD-10 will include a code for 23 weeks' gestation, but will still lag behind practices at some centers to consider resuscitation as early as 22 weeks' gestation.<sup>(39, 40)</sup> Using cost-charge ratios to estimate of hospital costs is not as exact as hospital-level micro-cost data, but this level of detail was unavailable on a national scale. Costs of post-hospital care, or other outcomes such as neurodevelopment or quality of life, are not reflected in this data. While we can quantify the amount spent on hospital admission, surviving ICU patients of all ages require further intervention after discharge. Post-discharge outcomes continue to be important research topics in neonatal literature, and are an emerging topic of interest for adult ICU patients as well; post-intensive care syndrome encompasses similar issues to neonatal follow-up including need for physical rehabilitation, mental health supports, and months-years of time lost from work after surviving critical illness.<sup>(41–43)</sup> Additional research is warranted about the ongoing cost of care for ICU survivors across the age spectrum.

## Conclusions

In summary, this study provides the first national estimates comparing use of mechanical ventilation for all age groups including preterm newborns, and comparing hospital costs for patients of all age groups receiving mechanical ventilation. Despite the high hospital costs for survivors, relatively low costs were incurred by non-surviving newborns < 24 weeks' gestation. From a pediatric perspective, attention should be directed toward improving outcomes for term infants, and toward safety of reducing length of stay for ventilated infants across all gestational ages.

## Acknowledgments

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## Abbreviations

<b>ICU</b>	intensive care unit
<b>ICD</b>	International Classification of Diseases
<b>NICU</b>	neonatal intensive care unit
<b>DOL</b>	day of life

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Figure 1a

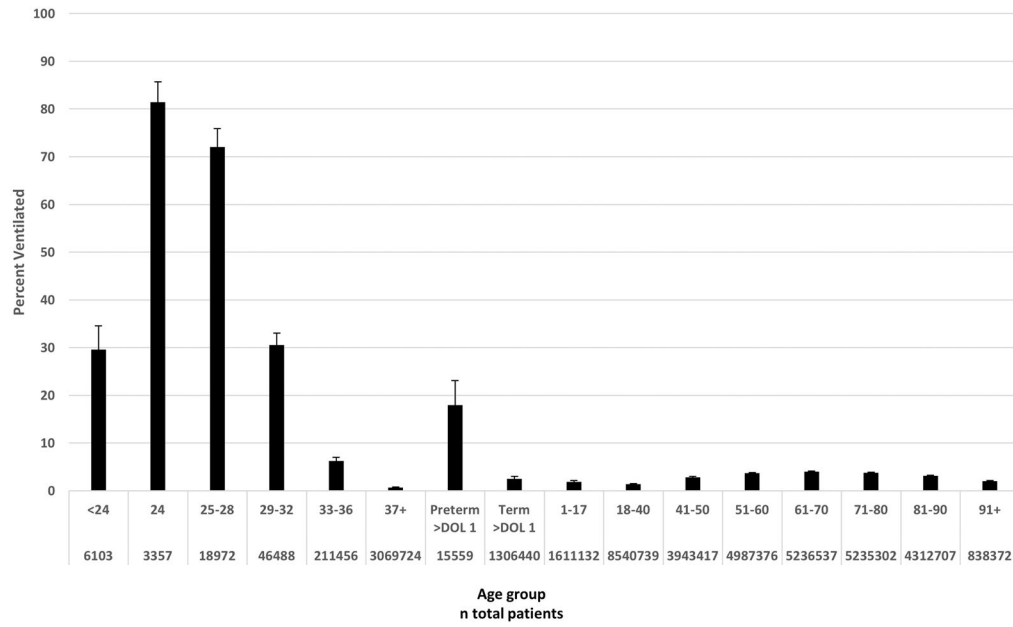


Figure 1a  
Figure 1b

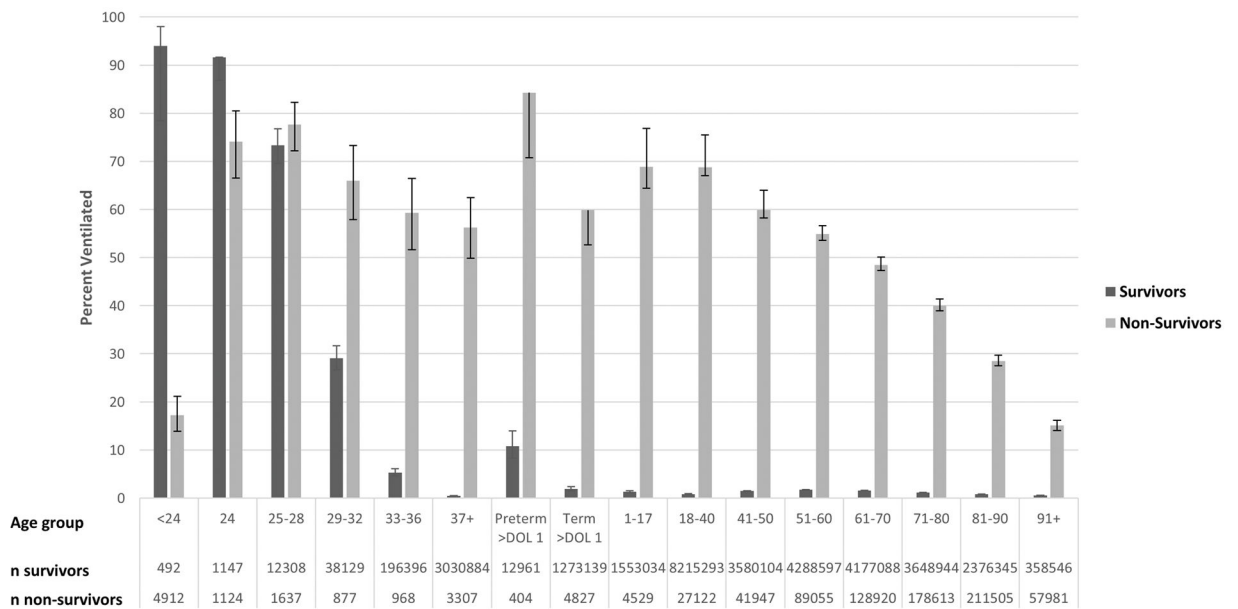


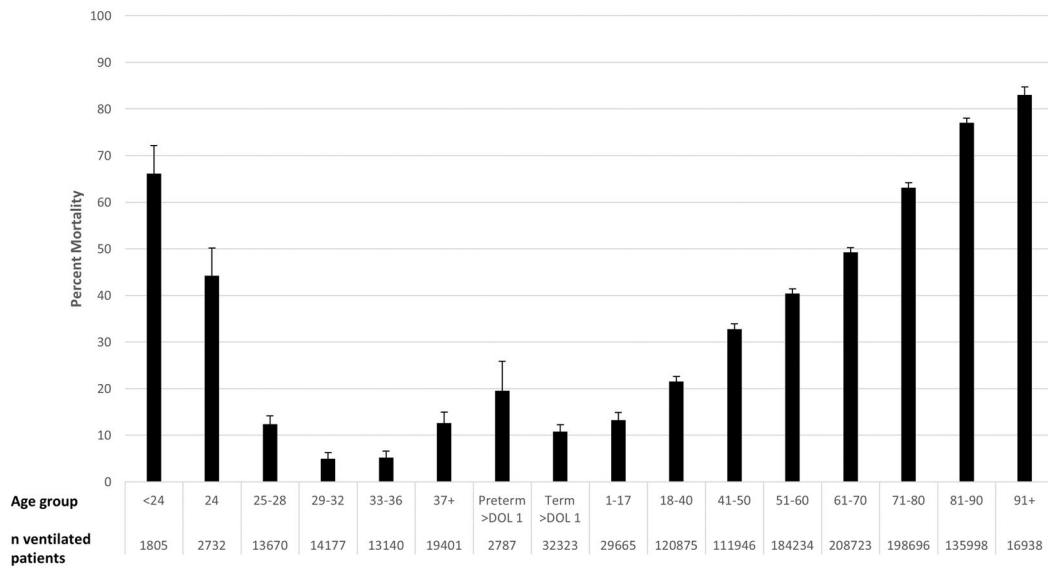
Figure 1b  
Figure 1.

Figure 1a. Use of mechanical ventilation by age group.

Figure 1b. Use of mechanical ventilation by age group for surviving and non-surviving patients.

Figure 1a shows the percentage of hospitalized patients in each age group who received mechanical ventilation, estimated using survey discharge weights. Error bars indicate 95% confidence intervals. The first row of the x axis displays the age group: newborns <24 weeks' gestation, 24 weeks' gestation, 25–28 weeks' gestation, 33–36 weeks' gestation, 37+ weeks' gestation, preterm infants (<37 weeks' gestation) admitted after day of life 0 or 1, term infants (37+ weeks' gestation) admitted after day of life 0 or 1, patients 1–17 years old, 18–40 years, 41–50 years, etc. The second row of the x axis displays the total estimated number of patients in each age group.

Figure 1b shows the percentage of hospitalized surviving and non-surviving patients in each age group who received mechanical ventilation, estimated using survey weights. Black columns show the percentage of hospitalized surviving patients who received mechanical ventilation; gray columns show the percentage of hospitalized non-surviving patients who received mechanical ventilation. Error bars indicate 95% confidence intervals. The first row of the x axis displays the age group, as detailed in Figure 1a. The second row of the x axis displays the total estimated number of surviving patients in each age group. The third row of the x axis displays the total estimated number of non-surviving patients in each age group.



**Figure 2. Mortality among patients receiving mechanical ventilation**

Figure 2 shows each age group’s rate of mortality before hospital discharge among patients receiving mechanical ventilation, estimated using survey weights. Error bars indicate 95% confidence intervals. The first row of the x axis displays the age group, as detailed in Figure 1a. The second row of the x axis displays the total estimated number of ventilated patients in each age group.

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Figure 3a

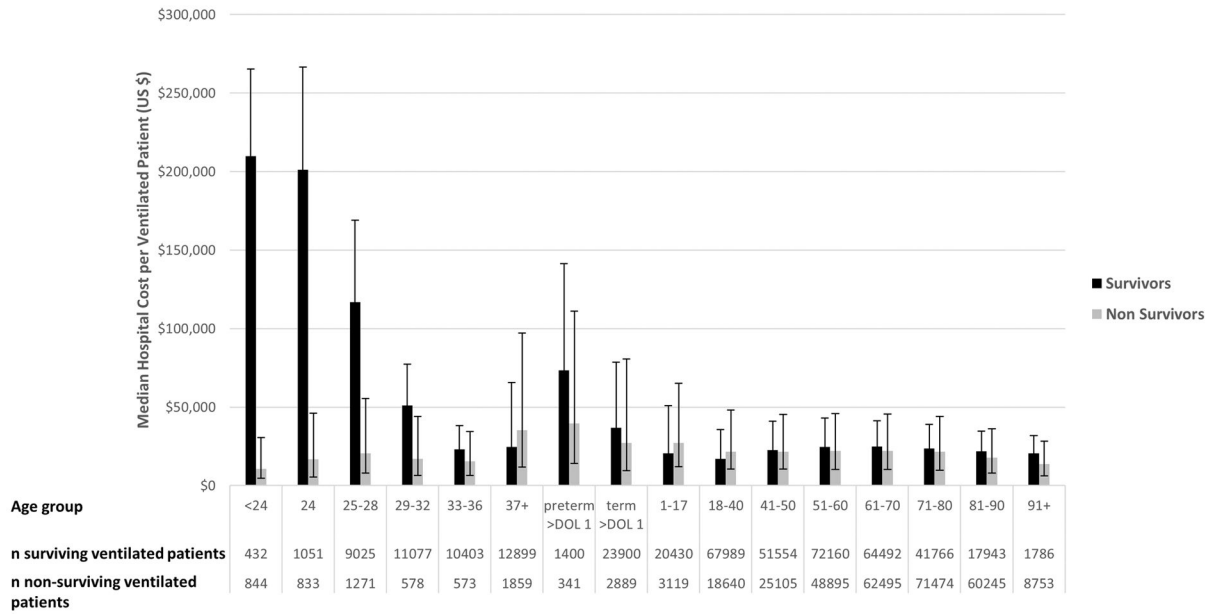


Figure 3a

Figure 3b

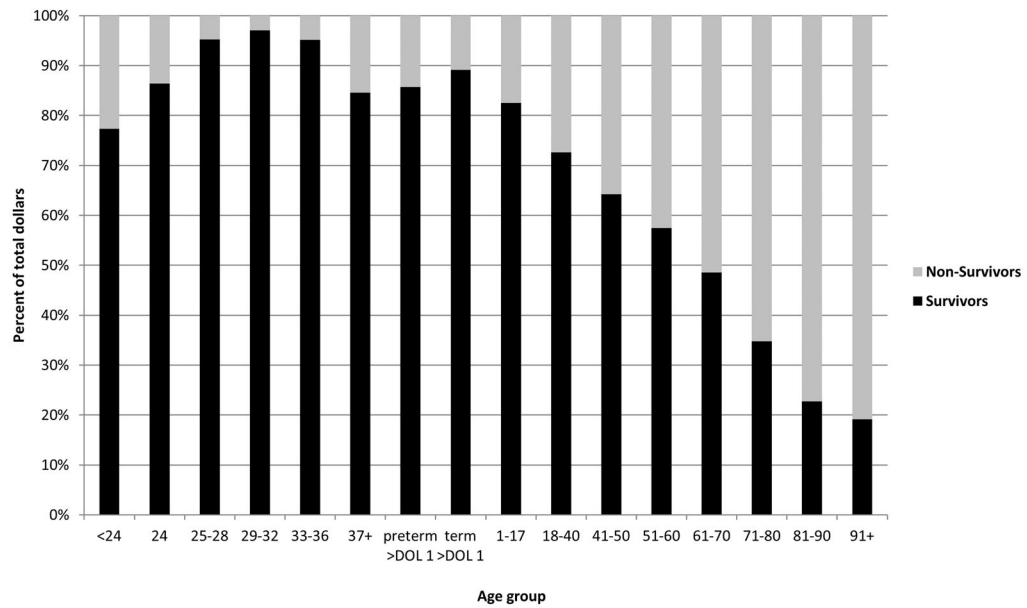


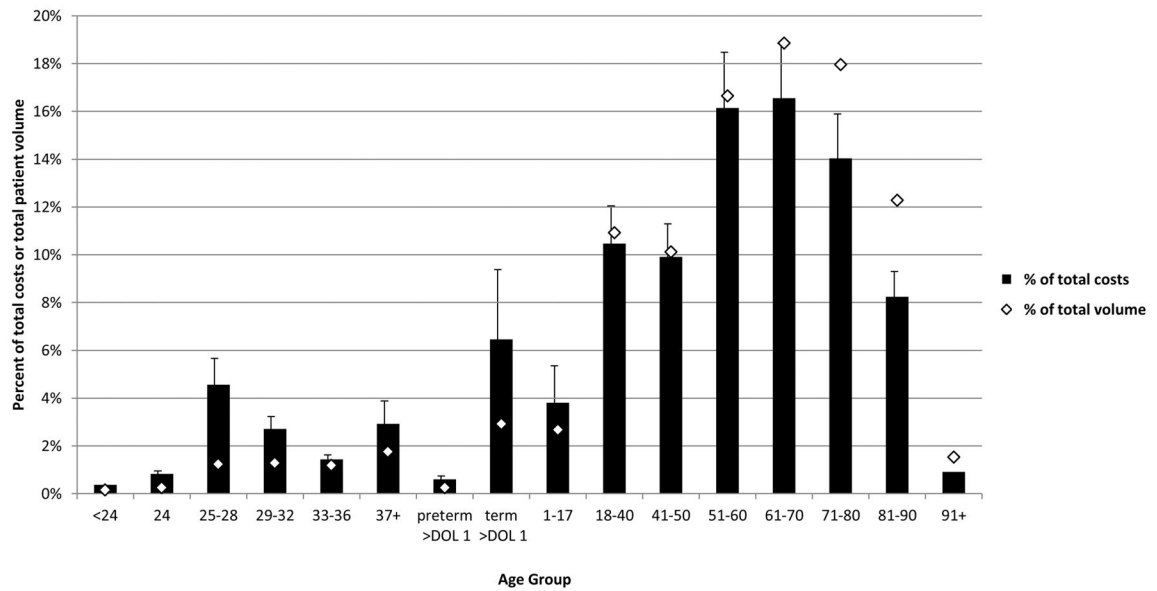
Figure 3b

Figure 3.

Figure 3a. Median cost of hospitalization among patients receiving mechanical ventilation. Figure 3b. Proportion of total hospital costs spent on surviving versus non-surviving patients receiving mechanical ventilation.

Figure 3a shows each age group's median cost of hospitalization for surviving and non-surviving patients receiving mechanical ventilation, estimated using Medicare charge-cost ratios and survey cost weights. Black columns show the median cost of hospitalization for surviving patients; gray columns show the median cost of hospitalization for non-surviving patients. Error bars indicate interquartile ranges. The first row of the x axis displays the age group, as detailed in Figure 1a. The second row of the x axis displays the total estimated number of surviving ventilated patients in each age group. The third row of the x axis displays the total estimated number of non-surviving ventilated patients in each age group. Figure 3b shows the proportion of total hospital costs spent on surviving versus non-surviving patients receiving mechanical ventilation, estimated using Medicare charge-cost ratios and survey cost weights. Black columns show the proportion of total hospital costs for surviving patients; gray columns show the proportion of total hospital costs for non-surviving patients. The x axis displays the age group, as detailed in Figure 1a.





**Figure 4. Relative proportions of total hospital costs versus patient volume among patients receiving mechanical ventilation**

Figure 4 shows the proportion of total hospital costs for ventilated patients in each age group, superimposed on the proportion of total hospital volume of ventilated patients in each age group. The black columns show each age group’s proportion of total hospital costs, estimated using Medicare charge–cost ratios and survey cost weights. Error bars indicate 95% confidence intervals. The white diamonds show each age group’s proportion of total patient volume among those receiving mechanical ventilation, estimated using survey weights. The x axis displays the age group, as detailed in Figure 1a.