The Mathematics of Morality in the NICU

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I have, sadly, no relevant financial relationships to disclose.

I have no conflict of interests to resolve.

I will not be discussing off-label use of meds.
Thanks to my colleagues at the University of Chicago

Kwang Lee
Jaideep Singh
Sudhir Sriram
Mike Schreiber
Bree Andrews
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Jessica Fry
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Susan Plesha-Troyke
Kirsten Weis

Annie Janvier
Joanne Lagatta
John Lantos
If suddenly you were forced to think hard about extremely premature infants, what would you want to know?

if you were:

• a doctor?
• a health policy-maker?
• a parent?
If you were a doctor,

• how frequently infants like this were born?
• how frequently they lived and died?
• how long they stayed in hospital?
• how they did if they survived the NICU?
As a policy-maker,

• how much do these babies cost?

• how do these expenses compare to other public health expenses, either in children or adults?
If you were a parent,

• “What will happen to my baby”?

• Not 100 more-or-less similar babies, but my baby?
If you were a parent, when would you want to know that answer?

- before birth?
- in the delivery room?
- after several days in the NICU?
- at the time of NICU discharge?
Are data like these available?

If so, who has them?
I will discuss four distinct data-related issues, as they impact the morality of NICU care --

• money
• outcomes
• prediction
• ‘worth’
Money
Some numbers for perspective --

In the U.S. each year:

- Babies born: 4,000,000
- People die: 3,000,000
- Babies < 1000g: 1% of 4,000,000 = 40,000
- Babies die: 0.6% of 4,000,000 = 24,000
- Babies < 1000g die: 1/3 of 40,000 = 12,000
What % of NICU resources are devoted to ELBW non-survivors, as opposed to resources devoted to ELBW babies who survive to discharge?

- 10 cents of every ELBW dollar on ELBW non-survivors?
- 50 cents?
- 90 cents?
"Wasted" Resources and Mortality vs Birth Weight

- % Non-Survivors
- % Resources Allocated to Non-Survivors

Mortality (%) vs Birth Weight (g)

- Birth Weight ranges: 450-500, 501-600, 601-700, 701-800, 801-900, 901-1000 g

- Mortality percentages: 0 to 100%
"Wasted" Resources and Mortality vs Birth Weight

Mortality (%)

Birth Weight (g)

% Non-Survivors
% Resources Allocated to Non-Survivors

Red circle indicates a specific weight range with higher mortality and resource allocation.
How can this be?

• Because doomed infants die relatively quickly
• The smallest and the sickest die the quickest
• And survivors are in the NICU a long, long time
A cross-cultural tidbit
We spend 10X more on dying MICU patients than dying NICU patients,

and there are 100X more dying adults than dying infants.
There are no credible financial arguments against neonatal intensive care.

If ICU cost-savings are desired, they should be found in adult ICUs, not NICUs.
Outcomes
Possible outcomes after birth

1. Death without resuscitation -- comfort care
2. Death in the NICU after initial resuscitation
3. Survival from NICU; neurologic impairment
4. Survival from NICU; neurologically intact
Moral calculations of the value of NICU care depend on the ‘valence’ assigned to each possible outcome

• If survival is the desired outcome, then ‘good’ outcomes are the ratio of survivors/all births

• If ‘intact’ survival is the only ‘good’ outcome, then ‘good’ outcomes are the ratio of intact survivors/all births
One more moral calculation

• If ‘trying and failing’ is not, on balance, negative, and if the only outcome to be feared is an impaired survivor, then ‘good’ outcomes are the percentage of intact survivors/all survivors
These differing moral weightings lead to very different conclusions about the ‘worth’ of NICU care for extremely premature babies
What about other countries?
Outcomes of Epicure Infants

Percent

Gestational Age (wks)

Epicure survival
Outcomes of Epicure Infants

- **Epicure survival**
- **Epicure % survivors w/o morb**

**Percent** vs **Gestational Age (wks)**

- At 22 weeks: 0%
- At 23 weeks: 10%
- At 24 weeks: 20%
- At 25 weeks: 40%
Bayley Scores for Epicure Survivors

Figure 2. Individual Scores on the Bayley Scales at 30 Months According to Gestational Age. Scores on the Mental Development Index (231 infants) are indicated by solid circles, and scores on the Psychomotor Development Index (225 infants) by open circles. The horizontal lines represent means.
What about our own hospital?
Survival and Morbidity Among Survivors 23-28wks

- Likelihood of Survival
- Likelihood of Survival w/o morbidity of Resuscitated Infants
- Likelihood of Surviving w/o Morbidity

Gestational Age in Weeks

<table>
<thead>
<tr>
<th>Gestational Age</th>
<th>Likelihood of Survival</th>
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Gestational Age in Weeks

Likelihood of Survival

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Gestational Age in Weeks

23 24 25 26 27 28

Likelihood of Survival
Survival and Morbidity Among Survivors 23-28wks
Survival and Morbidity Among Survivors 23-28wks

Likelihood of Survival

Likelihood of Survival w/o morbidity of Resuscitated Infants

Likelihood of Surviving w/o Morbidity

Gestational Age in Weeks

0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

23 24 25 26 27 28

Gestational Age in Weeks
In sum, moral calculations depend strongly on the ‘valence’ assigned to dying in the NICU

• If dying in the NICU has negative worth, then ‘good’ outcomes vary strongly as a function of GA

• If dying in the NICU is has some redeeming features, if ‘giving your kid a chance’ matters, and if impaired survivors are most feared, then ‘good’ outcomes do not depend much on GA
This leads to a problem with no solution:

• if the major concern is an infant with neuro-developmental impairment, then the GA to be most ‘feared’ from an ethical standpoint is not 23-24 weeks, but rather 25-26 weeks —--
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• because so many more infants will survive as GA increases, while ‘intactness’ of survivors does not vary much as GA increases.
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• because so many more infants will survive as GA increases, while ‘intactness’ of survivors does not vary much as GA increases.

• and, currently, we have no ethical options when confronted with 25-26 week infants – we resuscitate them
Prediction
When predicting outcomes, only two things matter

1) Timing

2) Positive Predictive Value
Outcome prediction in neonatology: a proposed timeline

Time and money

Prenatal counseling

Premature infant born

Delivery room resuscitation

Succeeds; to NICU

Trial of therapy

NICU Discharge

No resuscitation

Baby dies in DR

Baby dies in NICU

“Feeder-grower”

GA; ACS; twin? SGA

GA; ACS; twin? SGA; APGAR

SNAP; intuitions; HUS

ROP; BPD; CP
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    - Baby dies in NICU
  - Trial of therapy
    - Succeeds; to NICU
  - NICU Discharge
    - "Feeder-grower"

Variables:
- GA; ACS; twin? SGA
- GA; ACS; twin? SGA; APGAR
- SNAP; intuitions; HUS
- ROP; BPD; CP
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GA; ACS; twin? SGA
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Predicting Mortality

while the infant is on a ventilator
What predictors are there?

1. Algorithm

1. Intuition
What predictors are there?

1. Algorithm

1. Intuition
Serial SNAPPE-II scores do not distinguish survivors from non-survivors.
What predictors are there?

1. Algorithm

1. Intuition
On every day of mechanical ventilation, we asked caretakers (MDs, RNs) one question:

“do you think this baby will survive to be discharged, or die in the NICU”? 
A Quiz Question:

What % of ventilated VLBW infants are NEVER predicted to ‘die before discharge’?
More than half of ventilated infants were never predicted to die before NICU discharge.

Increasingly stringent predictions of death before discharge

How well did intuitions of “die before d/c” predict death in the NICU?

60% of infants were never predicted to die:
  almost all survived

40% of infants were predicted to die:
  half of these survived as well!
Imagine this conversation:

BTW, so much for the self-fulfilling prophecy concern
Morbidity Prediction

while the infant is on a ventilator
What data might we use to predict outcomes while a baby is on a vent in the NICU?

1. Intuitions
2. Algorithms
Intuitions

On every day of mechanical ventilation, we asked caretakers (MDs, RNs) one question:

“do you think this baby will survive to be discharged, or die in the NICU”? 
We then combined intuitions with head ultrasounds to predict two-year outcomes (death or MDI/PDI <70)
Head Ultrasound Abnormalities and Mortality or Morbidity

Risk of adverse outcome increased with more severely abnormal early head ultrasounds.

- Normal (n=130)
- Mild (n=28)
- Moderate (n=36)
- Severe (n=28)
Combinations of Head Ultrasound Abnormalities and Clinical Intuitions of Non-Survival in Predicting Mortality or Morbidity
Combinations of Head Ultrasound Abnormalities and Clinical Intuitions of Non-Survival in Predicting Mortality or Morbidity

![Graph showing combinations of head ultrasound abnormalities and clinical intuitions in predicting mortality or morbidity.](image-url)
Combinations of Head Ultrasound Abnormalities and Clinical Intuitions of Non-Survival in Predicting Mortality or Morbidity

Head Ultrasound

Percent mortality or Bayley MDI or PDI < 70

Normal (n=130)  Mild (n=28)  Moderate (n=36)  Severe (n=28)
Combinations of Head Ultrasound Abnormalities and Clinical Intuitions of Non-Survival in Predicting Mortality or Morbidity

Percent mortality or Bayley MDI or PDI < 70

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Head Ultrasound
Combination of Head Ultrasound Abnormalities and Clinical Intuitions of Non-Survival in Predicting Mortality or Morbidity
How much better are these predictors than gestational age?
Percent Mortality or Bayley MDI or PDI < 70 Stratified by NICU Events:
Gestational Age

- ALL (n=177) p = 0.002
- No events (n=98) p = 0.949
- One event (n=51) p = 0.311
- Two events (n=28) p = 0.520

Legend:
- 23-24 weeks
- 25+ weeks
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\[ p = 0.520 \]

- **ALL (n=177)**: p = 0.002
- **No events (n=98)**: p = 0.949
- **One event (n=51)**: p = 0.311
- **Two events (n=28)**:
How much do we learn, and when do we learn it, compared to what we know at the time of delivery?
Survival with Bayley MDI and PDI > 70 as a Function of Time by Gestational Age

- 23-24 Weeks, No Events
- 25+ Weeks, No Events
- 23-24 Weeks, 1 Event
- 25+ Weeks, 1 Event
- 23-24 Weeks, 2 Events
- 25+ Weeks, 2 Events

Percent Survival with Bayley MDI and PDI > 70

Day of Life
Here’s a nice analogy:

Imagine if you were allowed to bet on the outcome of a soccer or baseball game – not just before the game began, but at any time prior to the end …..

Don’t you think you’d become better at predicting the winner as time passed?
Likelihood of Winning if Leading After Inning

Inning

Probability of winning
Probability of Winning if a Team is Leading at Various Times after Kick Off

Time into Match (minutes)

Probability of Winning
If we let you bet on baseball or soccer while the match was still going, you would do a lot better than the pre-match line;

Why don’t we do the same for the parents of ELGANs?
What have we learned?

- Don’t have to decide at birth
- Time will help sort things out
- Moral worth is not settled
What more do we need to know?

How much do parents value ....

1. Survival from NICU; neurologically intact
2. Survival from NICU; neurologic impairment
3. Death in the NICU after initial resuscitation
4. Death without resuscitation -- comfort care
Final ethical implications

- Small claim –
  We should use these data to counsel our parents
Final ethical implications

• Small claim –
  We should use these data to counsel our parents

• Large claim –
  We should offer all parents the opportunity to resuscitate their infants in the DR and predict while they are in the NICU
Final ethical exhortation

• Process matters
• Don’t abandon your patients
• That's what ‘attending’ means
Thank you
What is a premie worth?
Best interest vs accepting family refusal of care
Best interest vs accepting family refusal of care
Best interest vs accepting family refusal of care
Best interest vs accepting family refusal of care
### Epicure Disability Rates at 30 Months

<table>
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<th>Gestational age (wks)</th>
<th>&lt;23</th>
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<th>25</th>
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<tr>
<td>Bayley scores</td>
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<td>mental</td>
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<tr>
<td>No sensory disability</td>
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