

BiliCam: Using Mobile Phones to Monitor Newborn Jaundice



Lilian de Greef, Mayank Goel, Min Joon Seo,
Eric C. Larson, James W. Stout MD MPH,
James A. Taylor MD, Shwetak N. Patel

dub



ubicomplab
UNIVERSITY OF WASHINGTON
UW Medicine



What is BiliCam?



A smartphone-based system to assess newborn jaundice.



Overview



100 newborn
clinical study

Performs similarly to an
FDA approved device

\$7000



What is BiliCam?



A smartphone-based system to assess newborn jaundice.



What is BiliCam?



A smartphone-based system
to assess **newborn jaundice**





Jaundice

yellowish skin from
excess bilirubin



peaks in 3-5 days

84% of all newborns

extreme levels devastating



worry

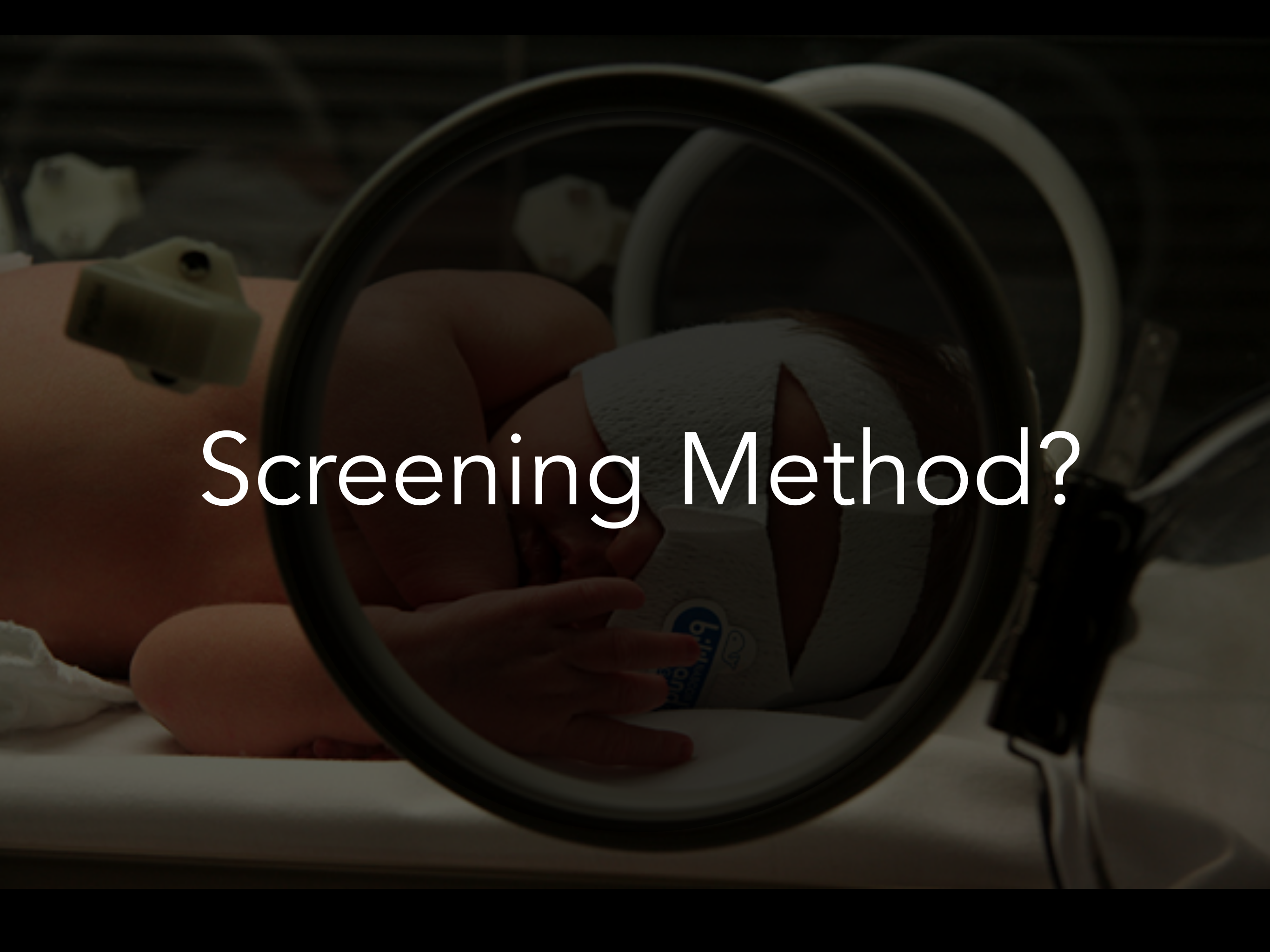




A newborn baby is lying in a blue phototherapy incubator. The baby is wearing a white cap and a white blanket. The incubator has a large circular opening on the right side. The text "1 in 14 undergo phototherapy" is overlaid on the image.

1 in 14 undergo
phototherapy



A newborn baby is lying in a hospital bed, viewed through a circular frame. The baby is wearing a white diaper with a blue logo. The text "Screening Method?" is overlaid in white. The background is dark and out of focus, showing some medical equipment and a white cloth.

Screening Method?



Total Serum Bilirubin



TSB

Medical Gold
Standard





Transcutaneous Bilirubinometer



TcB



TcB



TcB



\$7000

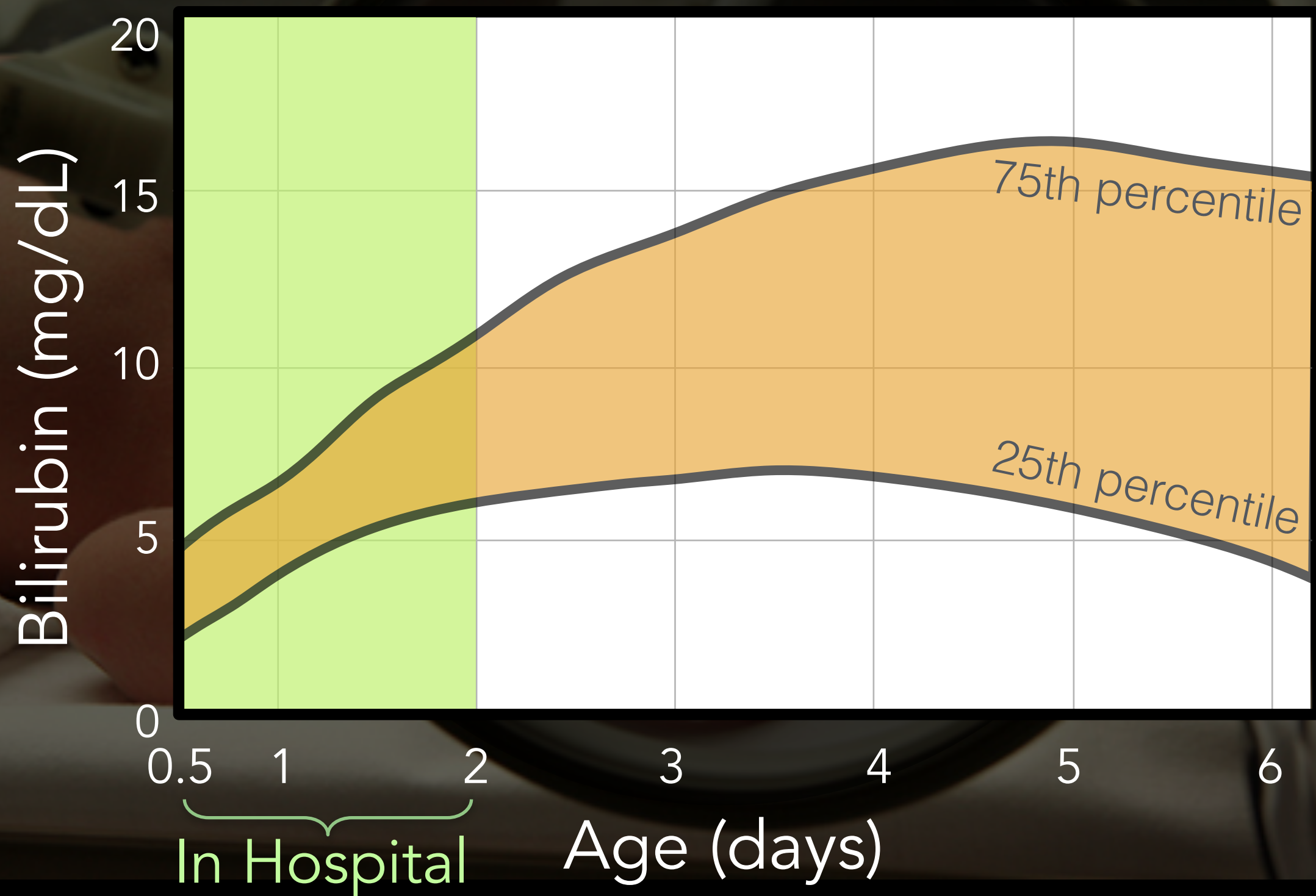
Non-invasive

Quick results

Correlates 0.75-0.93

Screening tool for TSB

Newborn Bilirubin Levels



Screening Challenges

In Hospital

At Home

Visual Assessment

- Parents
- Many physicians
- Traveling practitioners

Tend to underestimate

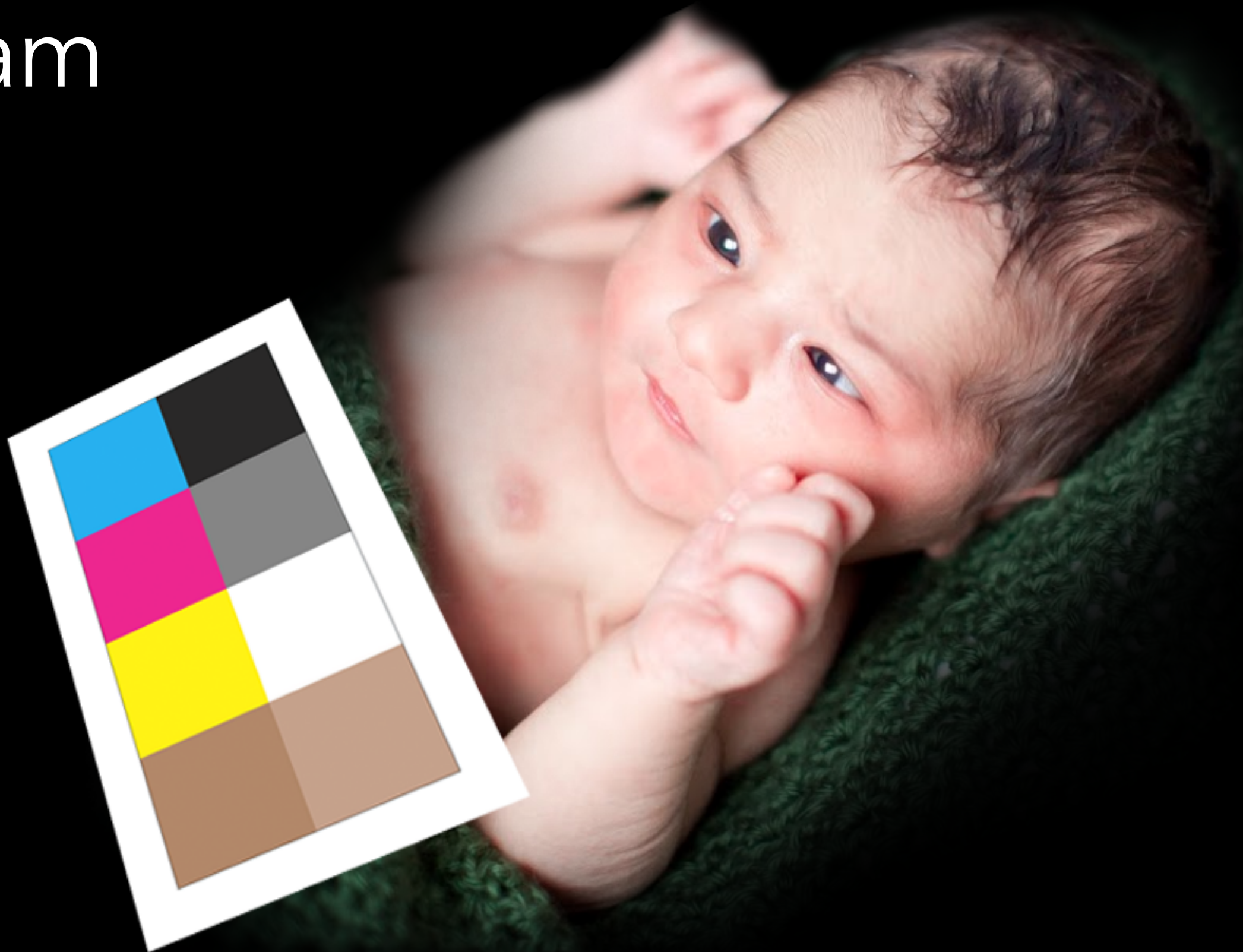


BiliCam



cost
portability
accessibility

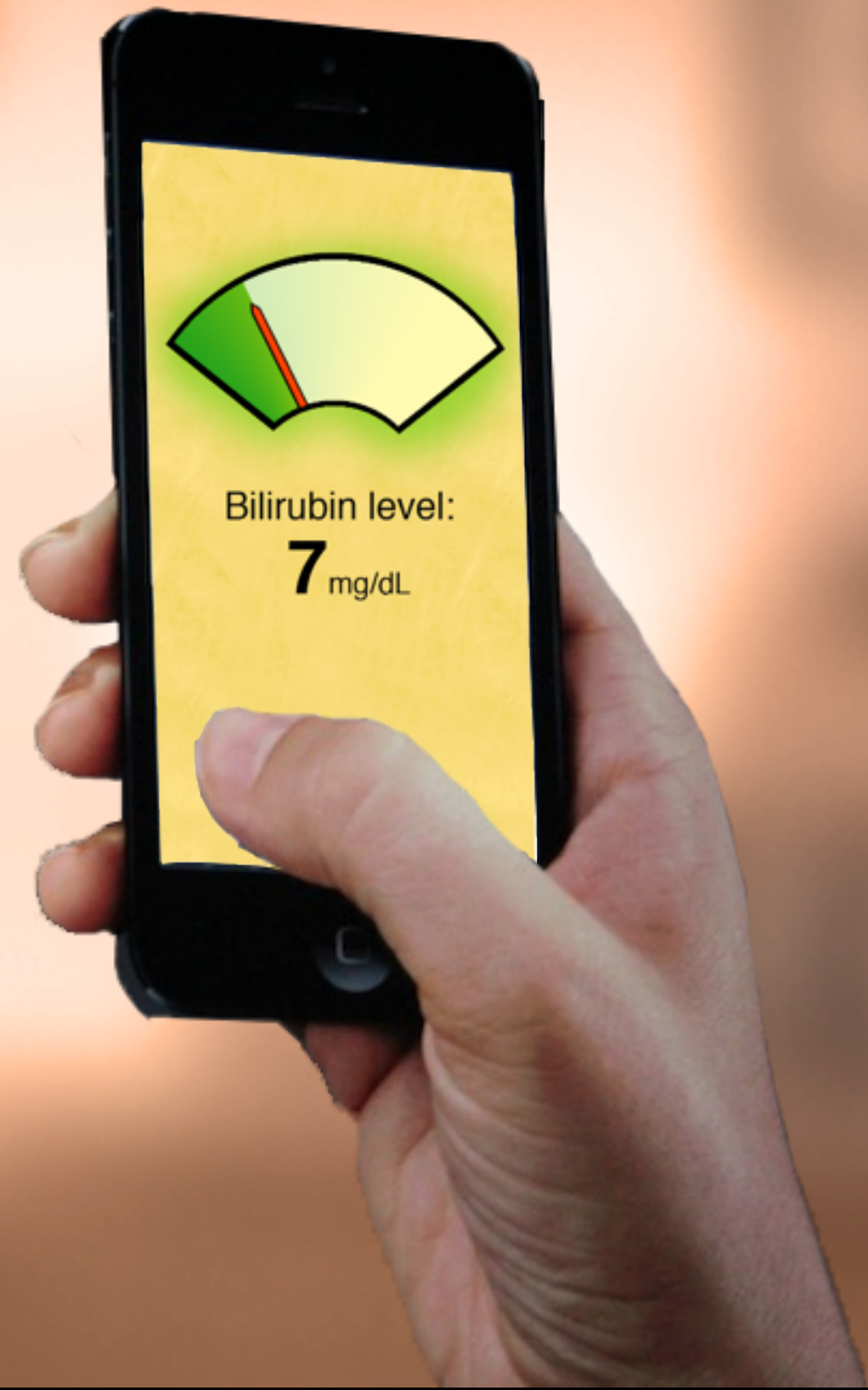
Using BiliCam



Using BiliCam



Using BiliCam



Study Design

Informed by 6 months of formative work

- interviews
- focus groups
- contextual inquiry
- pilot study (40 newborns)

Study Design

100 newborn participants

- <1 day old when enrolled
- 59% white

2 medical centers

Data collected by medical
professionals using iPhone 4S

Data Collected (for each participant)



Photos: with &
without flash



TSB (ground truth)



TcB (control)

Data Collected (for each participant)

3 - 5 days old



Photos: with &
without flash



TSB (ground truth)



TcB (control)

Data Collected (for each participant)

< 1 day old



Photos: with &
without flash

3 - 5 days old



Photos: with &
without flash

TSB (ground truth)



TcB (control)

Data Collected (for each participant)

"Baseline"

< 1 day old



Photos: with &
without flash

"Follow-Up"

3 - 5 days old



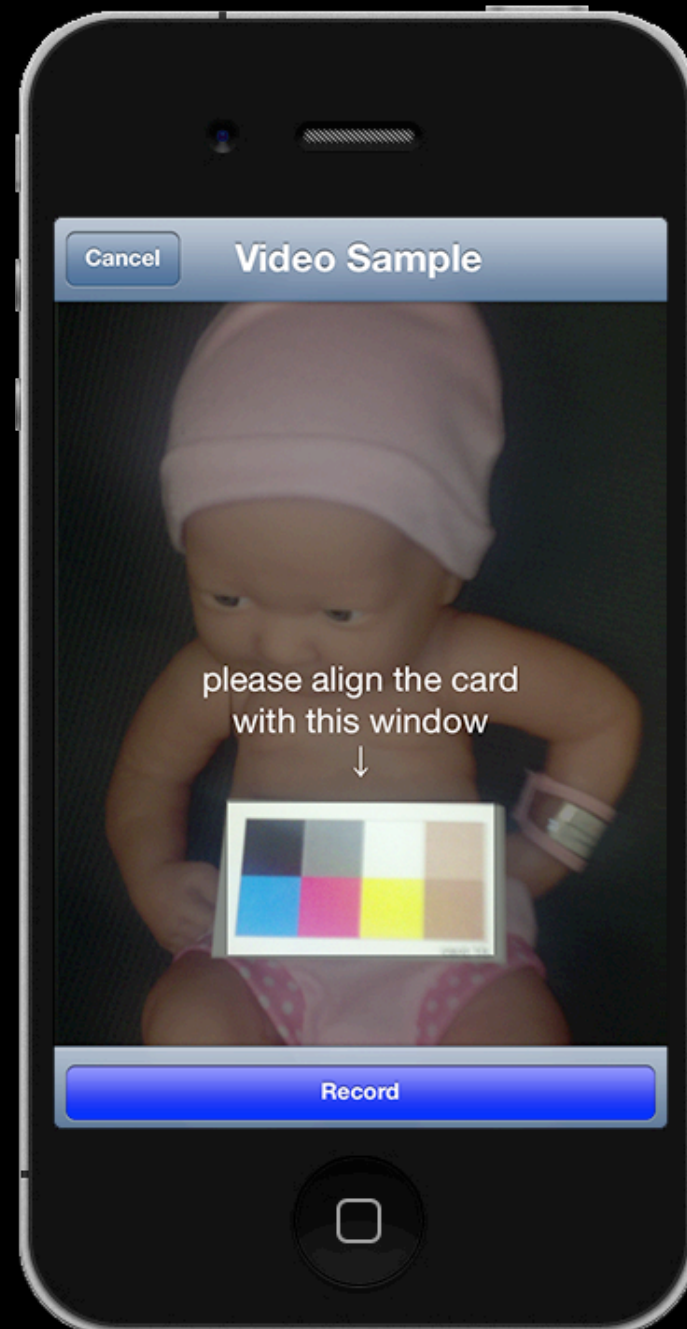
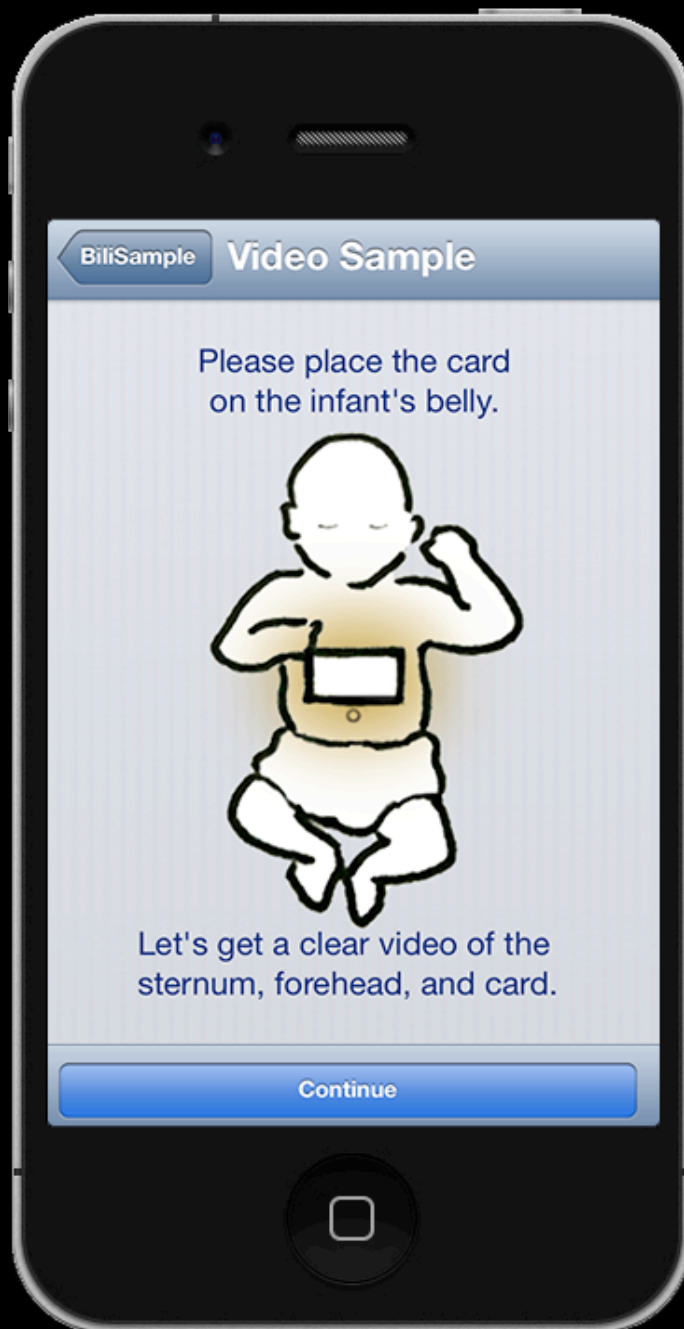
Photos: with &
without flash



TSB (ground truth)

TcB (control)

Data Collection App



Standardize

- white balance
- card position
- phone position

Noisy Data



Automatic Quality Control

Ideal



Glare



Overexposed



Occlusion



Shadow



Underexposed



Algorithm Overview



**Color
Balance**



**Extract
Features**



**Apply
Regressions**



**Bilirubin
Estimate**

Algorithm Overview



**Color
Balance**



**Extract
Features**



**Apply
Regressions**



**Bilirubin
Estimate**

Color Balance



Different lighting conditions

Color Balance



Algorithm Overview



Color
Balance



Extract
Features

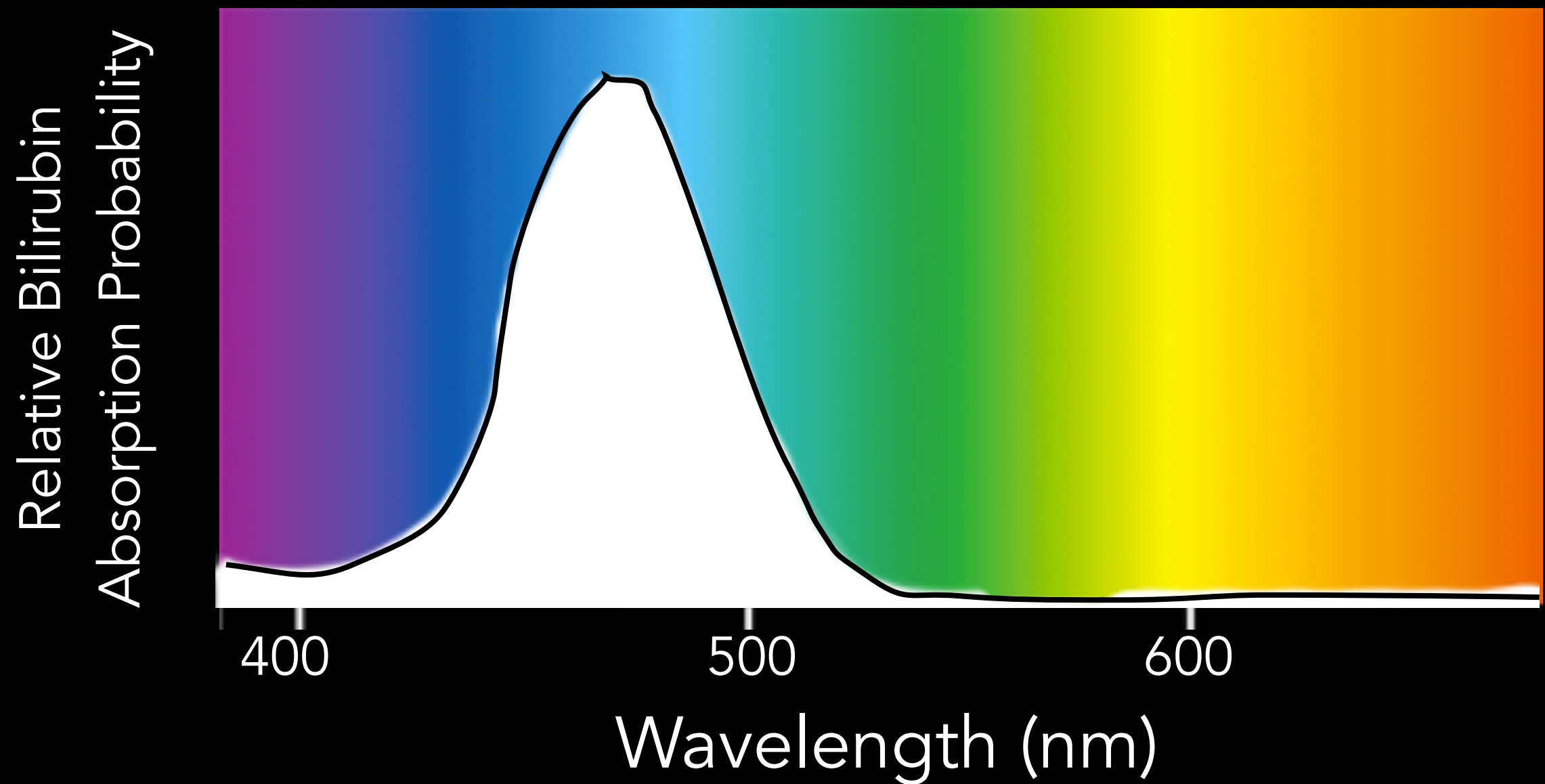


Apply
Regressions



**Bilirubin
Estimate**

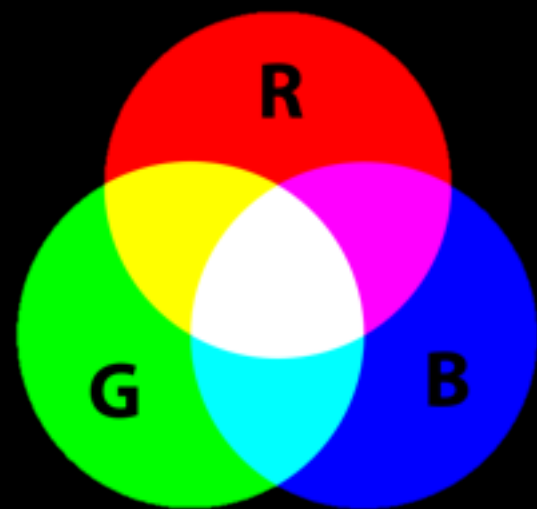
Bilirubin Absorption Properties



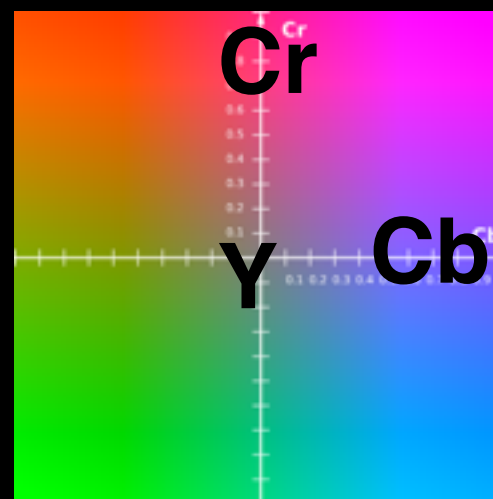
Feature Extraction



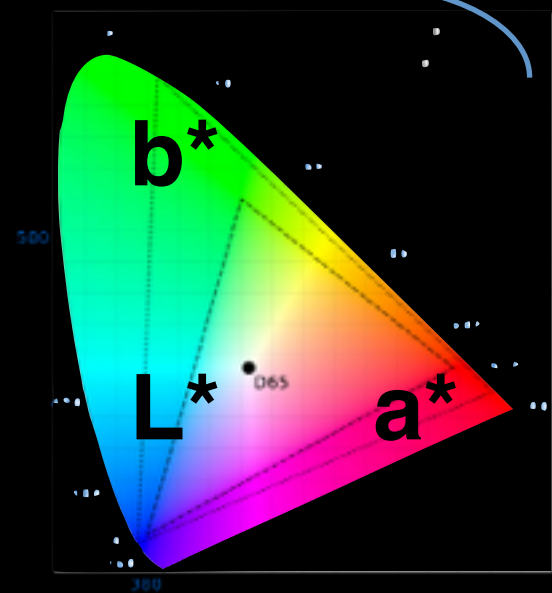
with & without flash



RGB



YCbCr



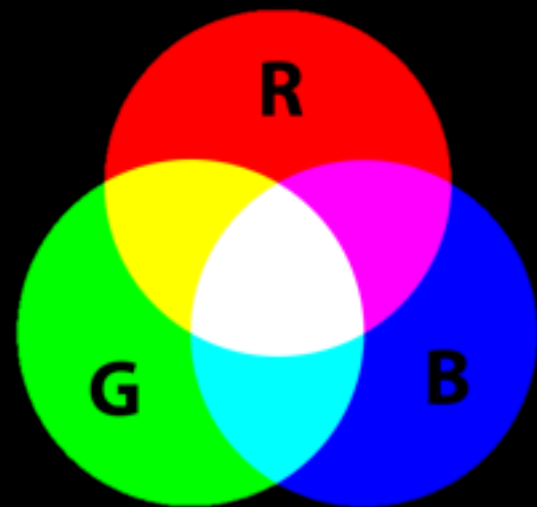
L*a*b*

Feature Extraction

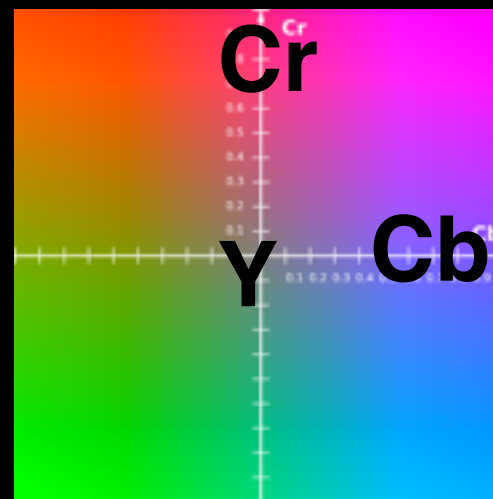


Gradient
(of RGB channels)

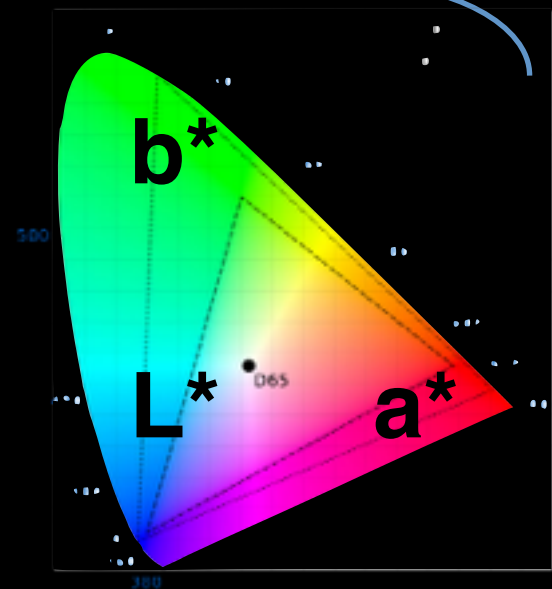
with & without flash



RGB

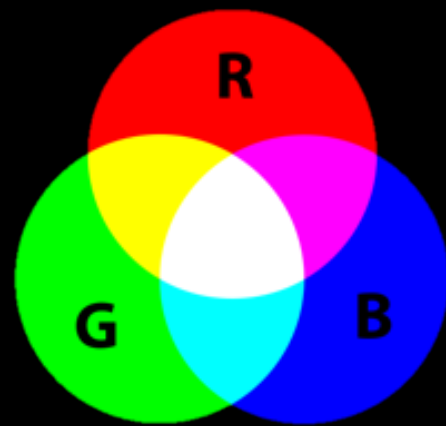


YCbCr

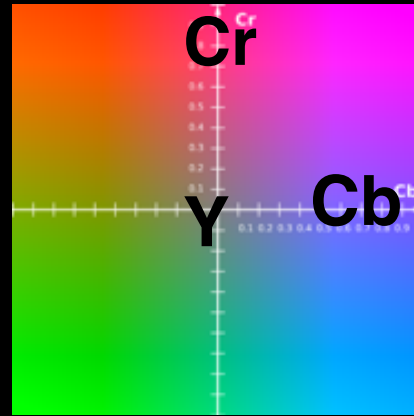


L*a*b*

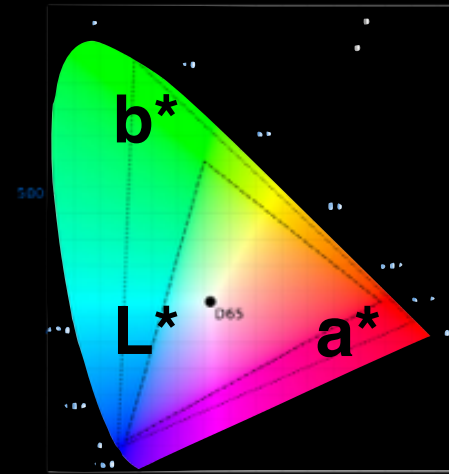
Feature Extraction



RGB



YCbCr



L*a*b*

Gradient
(of RGB channels)

with flash	3	3	3	3
without flash	3	3	3	0

total: 21 features

Processing Features

- scaled
 - unit variance
 - zero mean
- PCA
 - 6 component features
 - to reduce redundancy
- use both scaled & PCA

Algorithm Overview



Color
Balance



Extract
Features

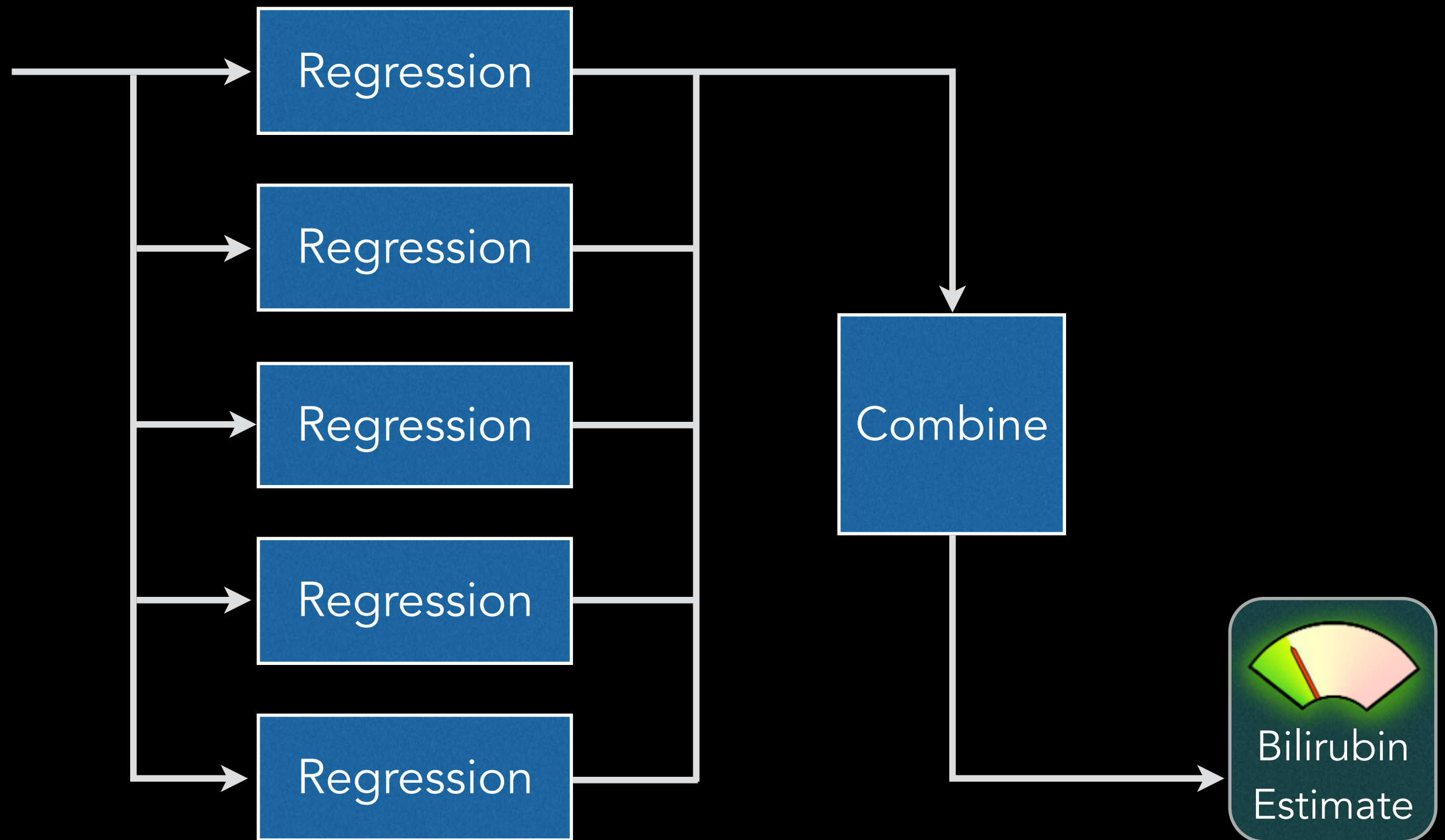


Apply
Regressions

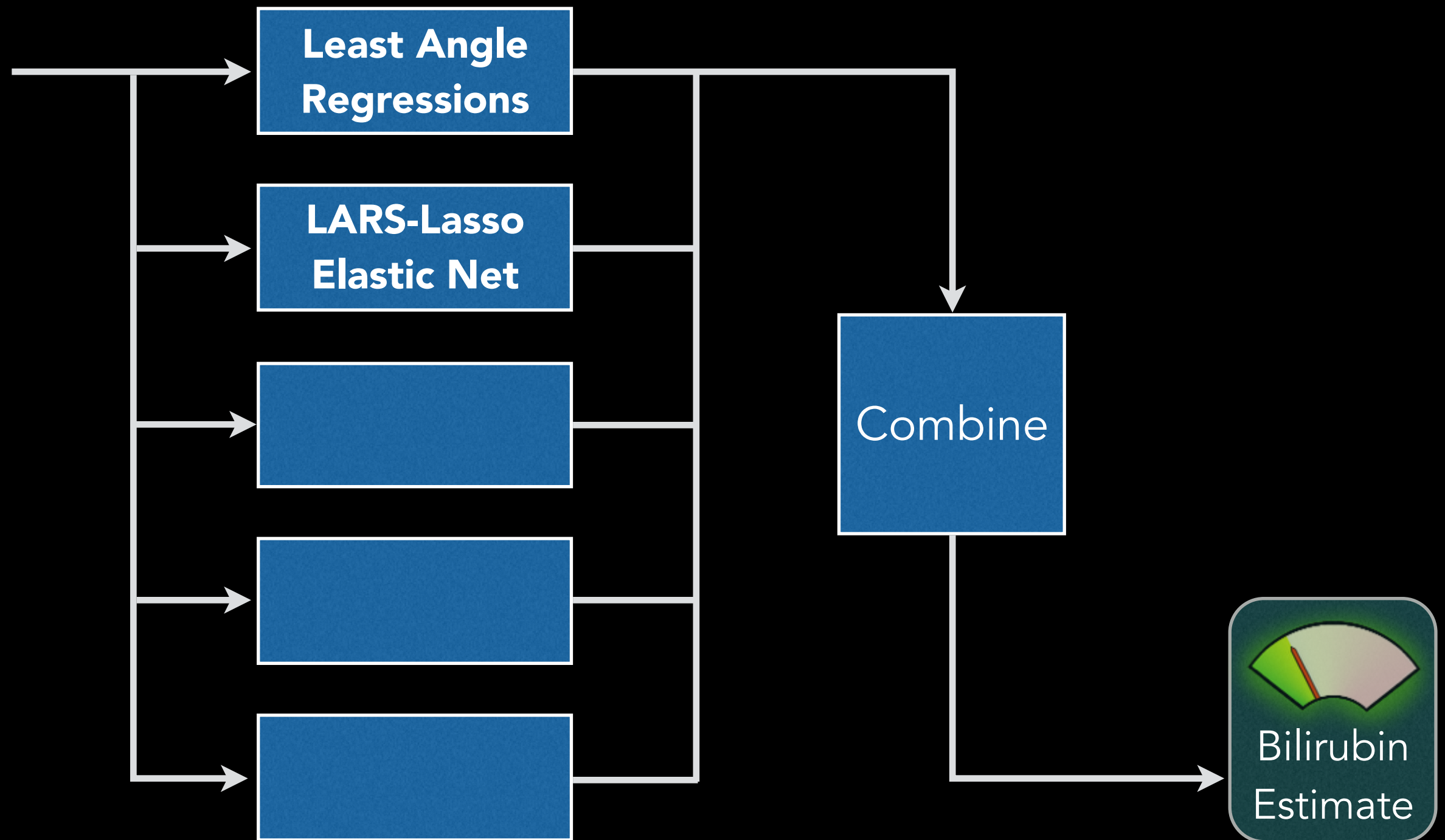


**Bilirubin
Estimate**

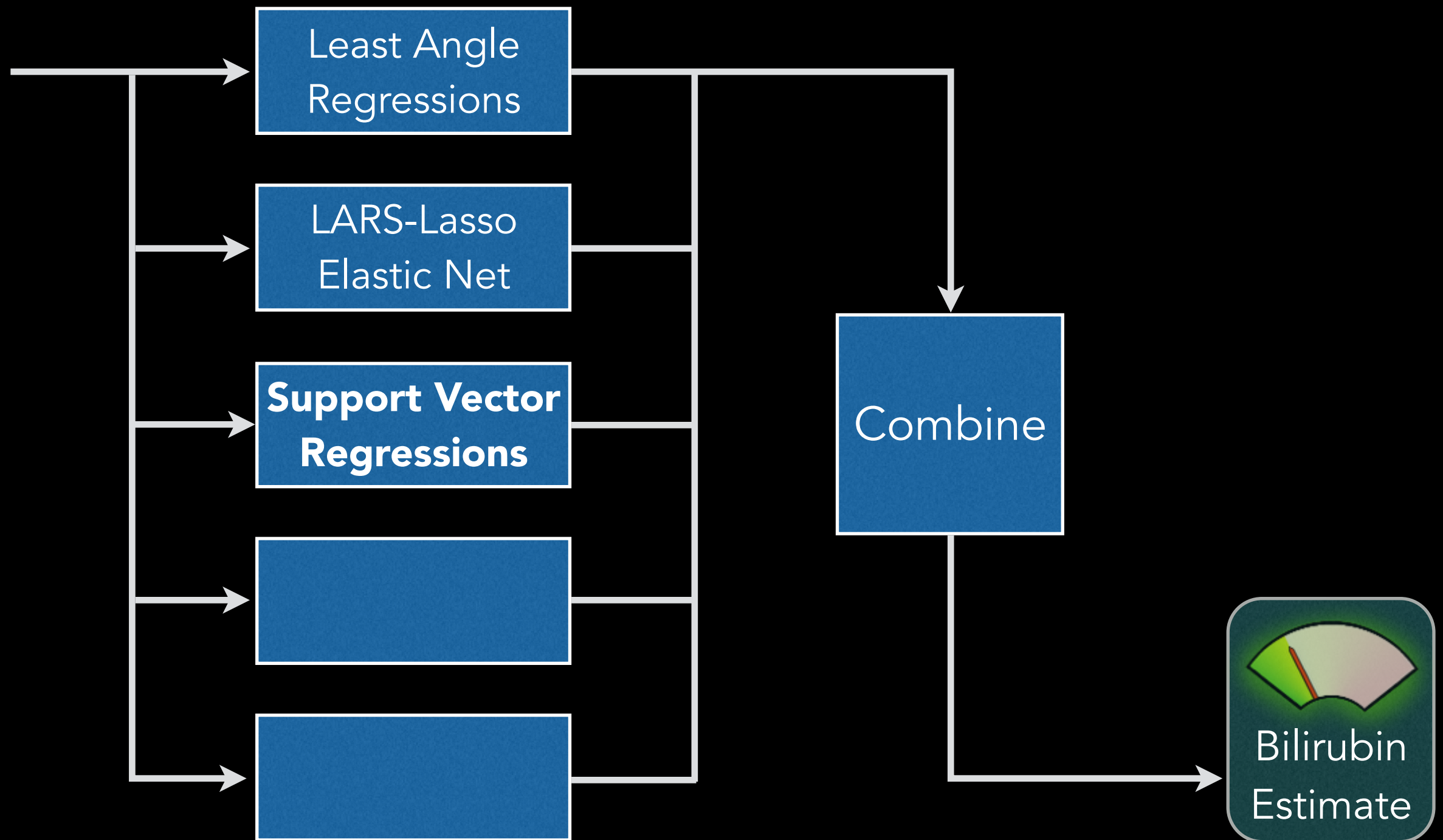
Regression Ensemble



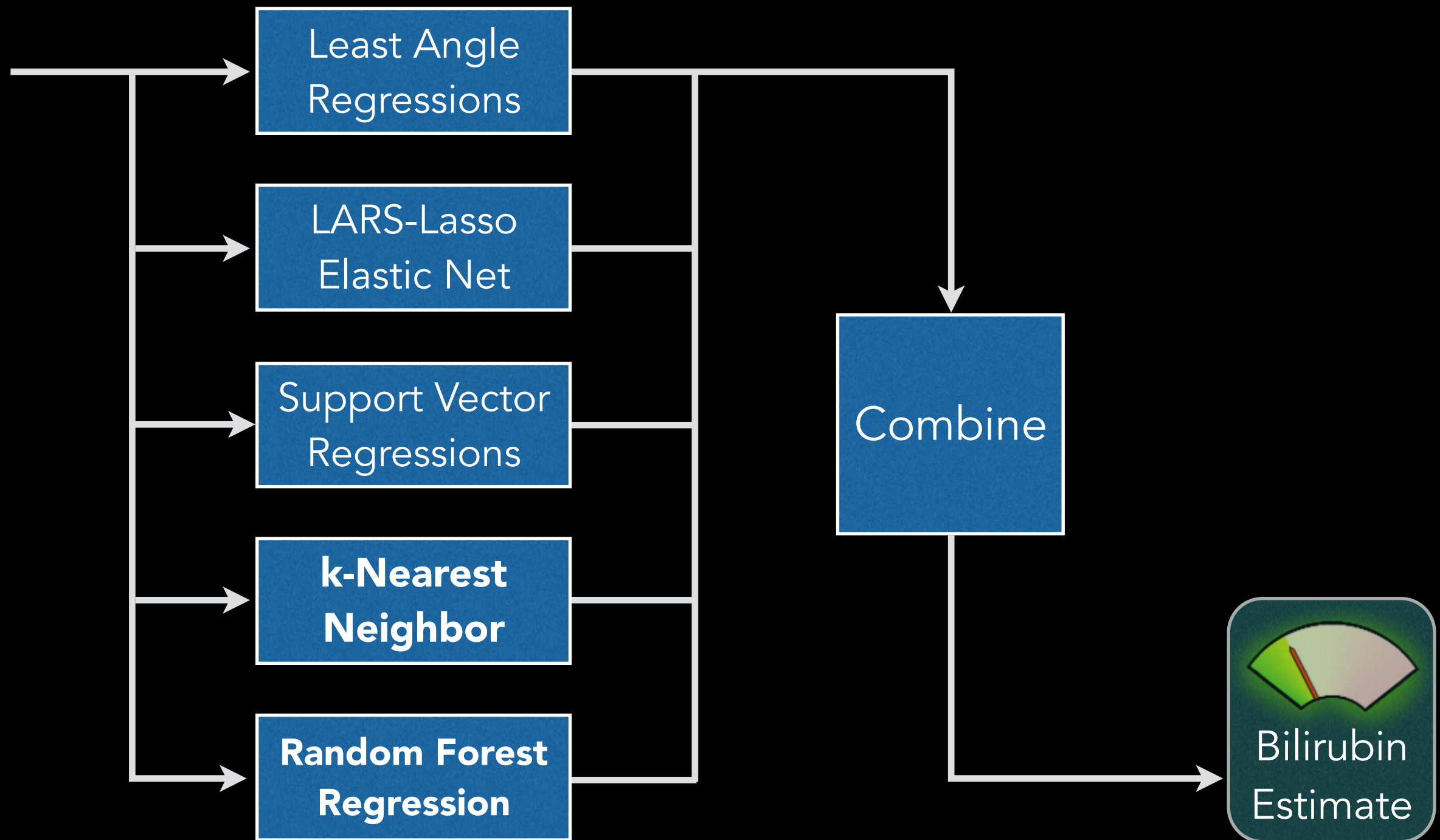
Regression Ensemble



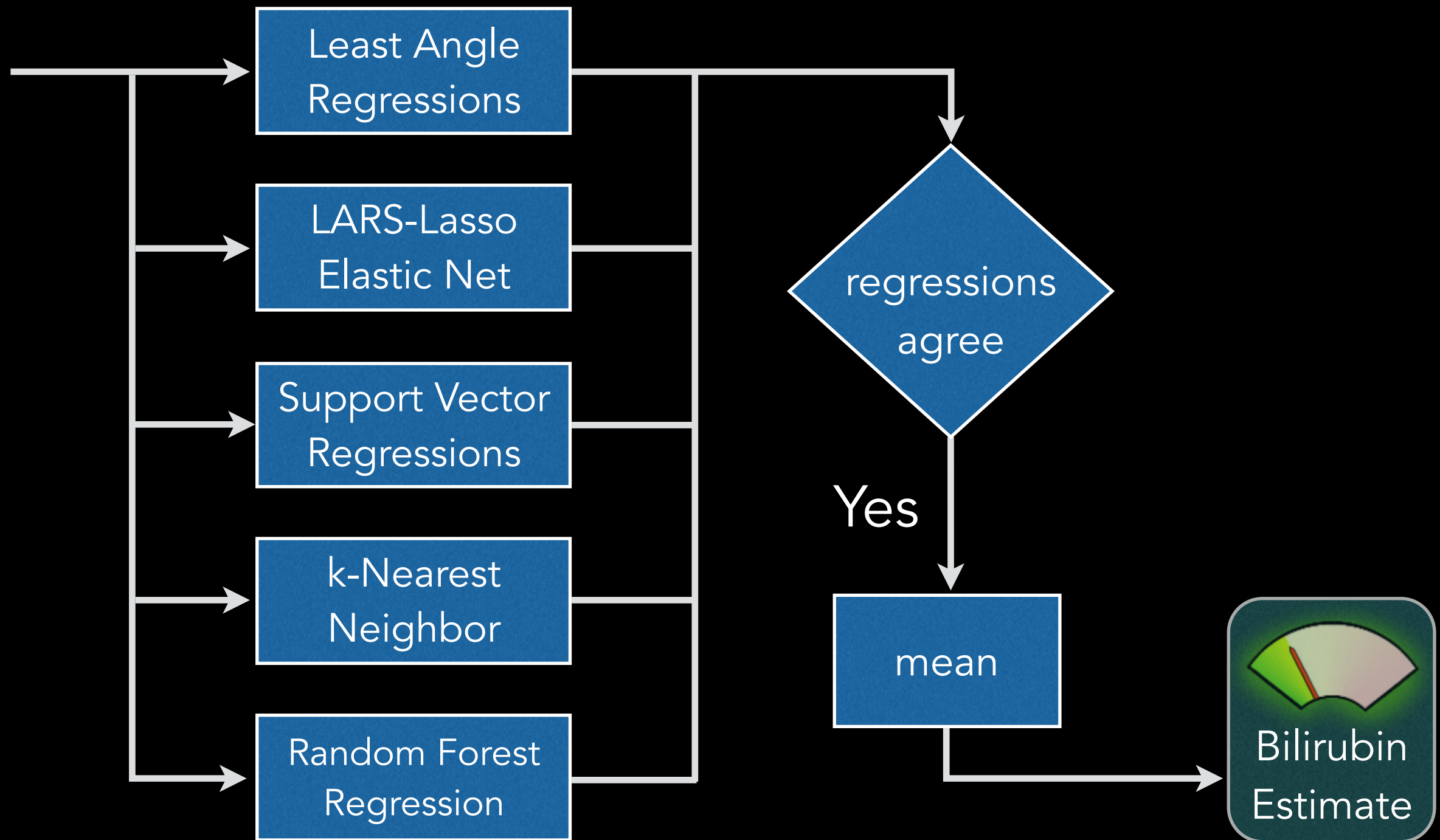
Regression Ensemble



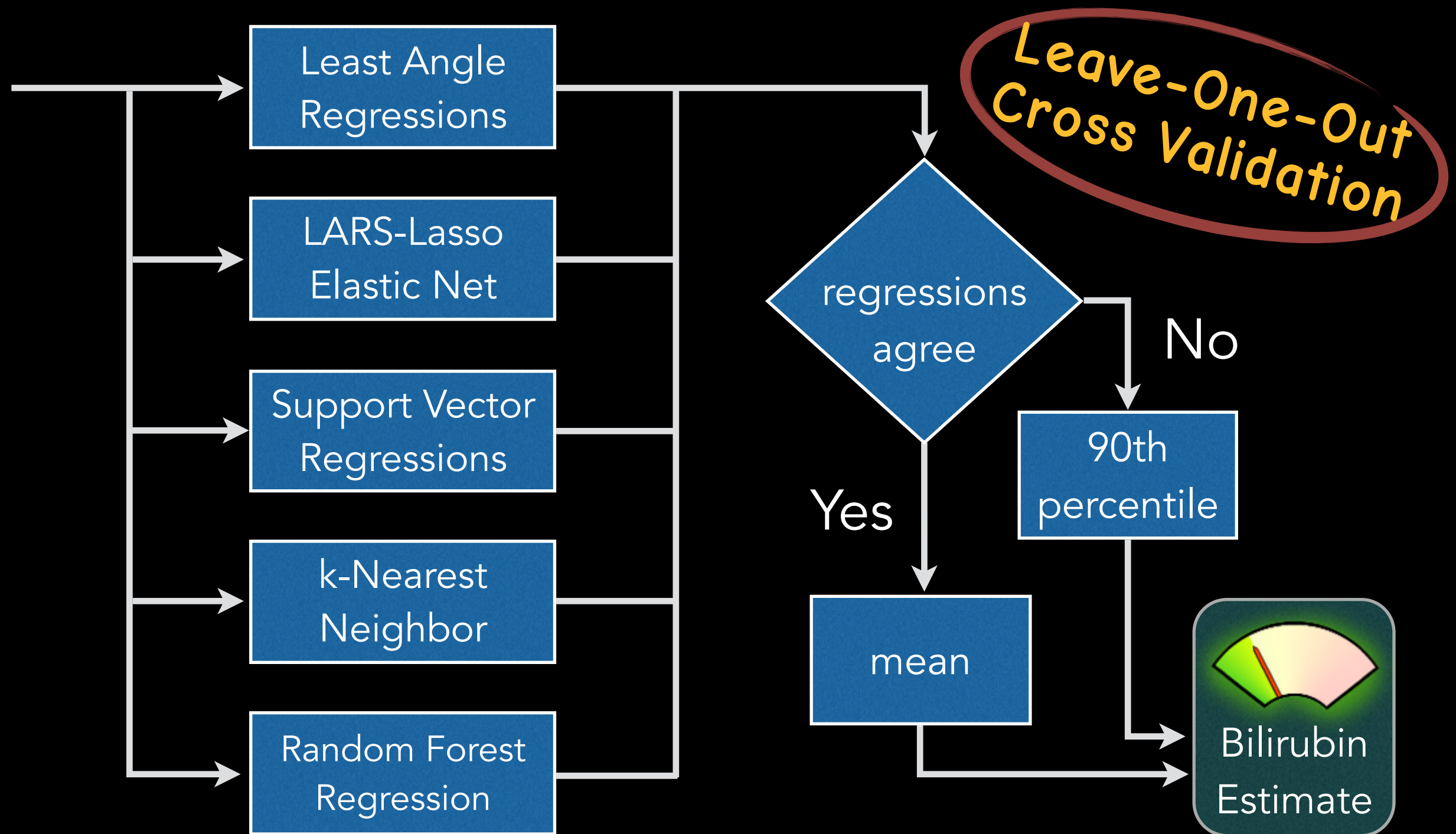
Regression Ensemble



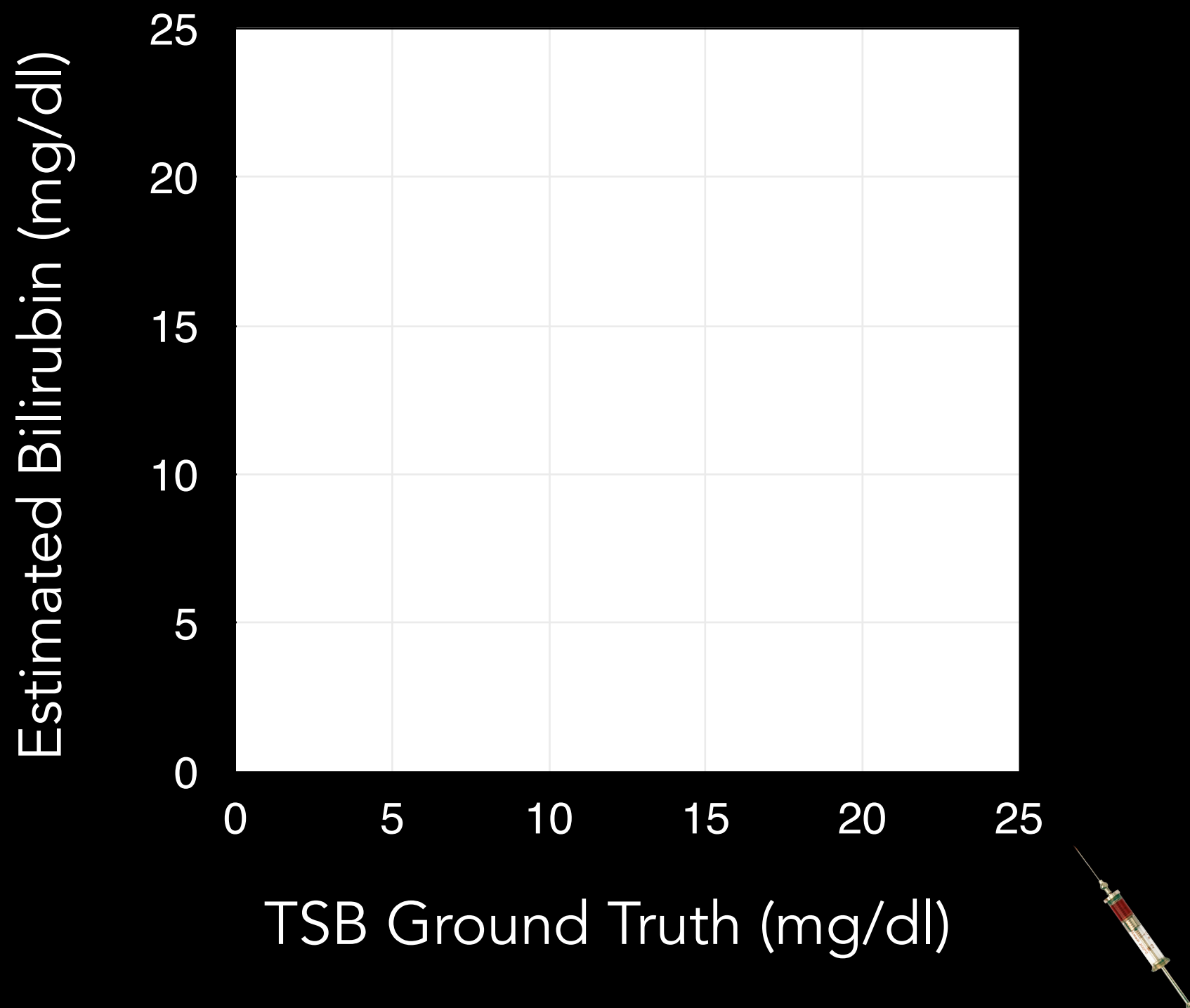
Regression Ensemble



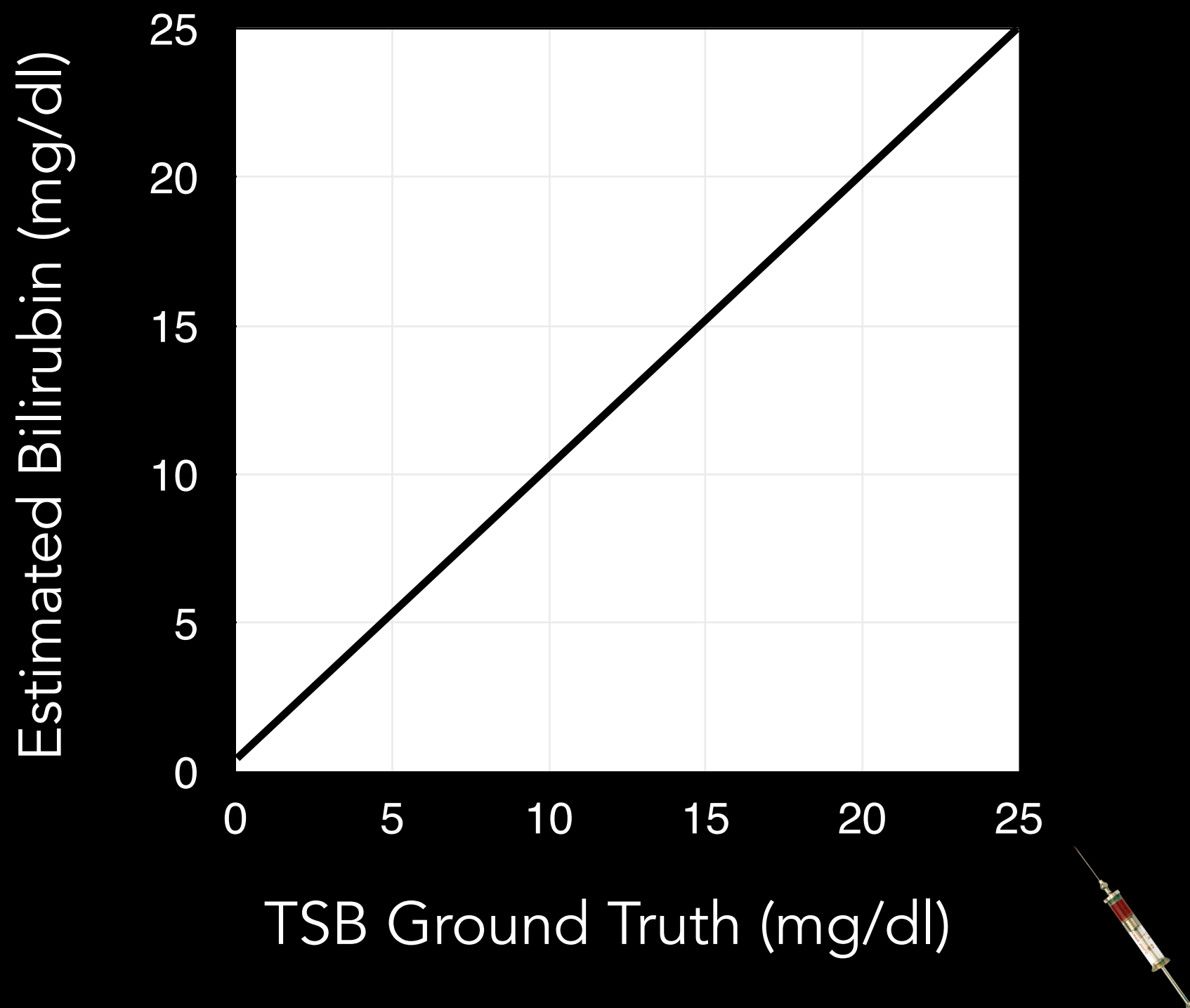
Regression Ensemble



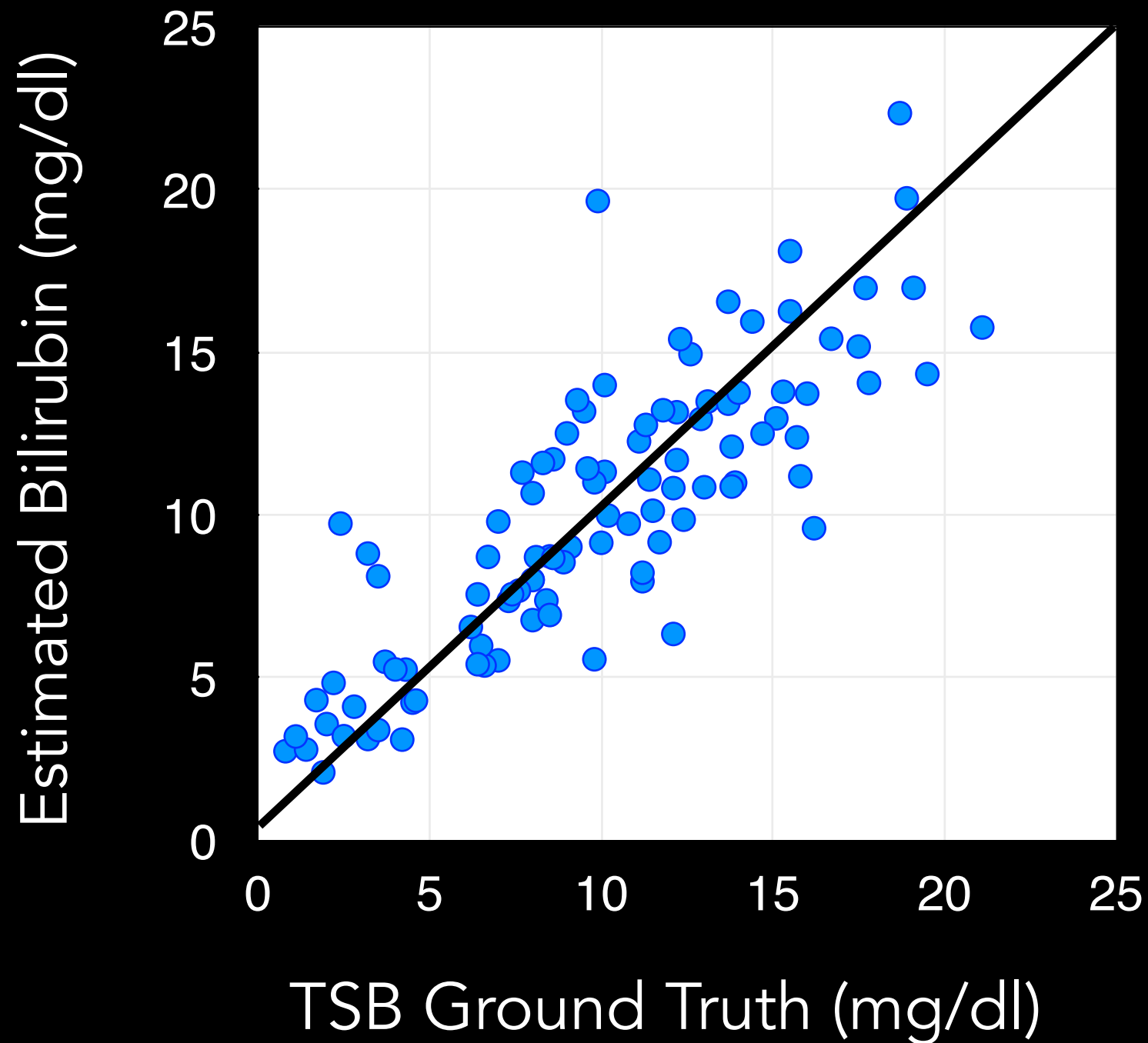
Results



Results



Results

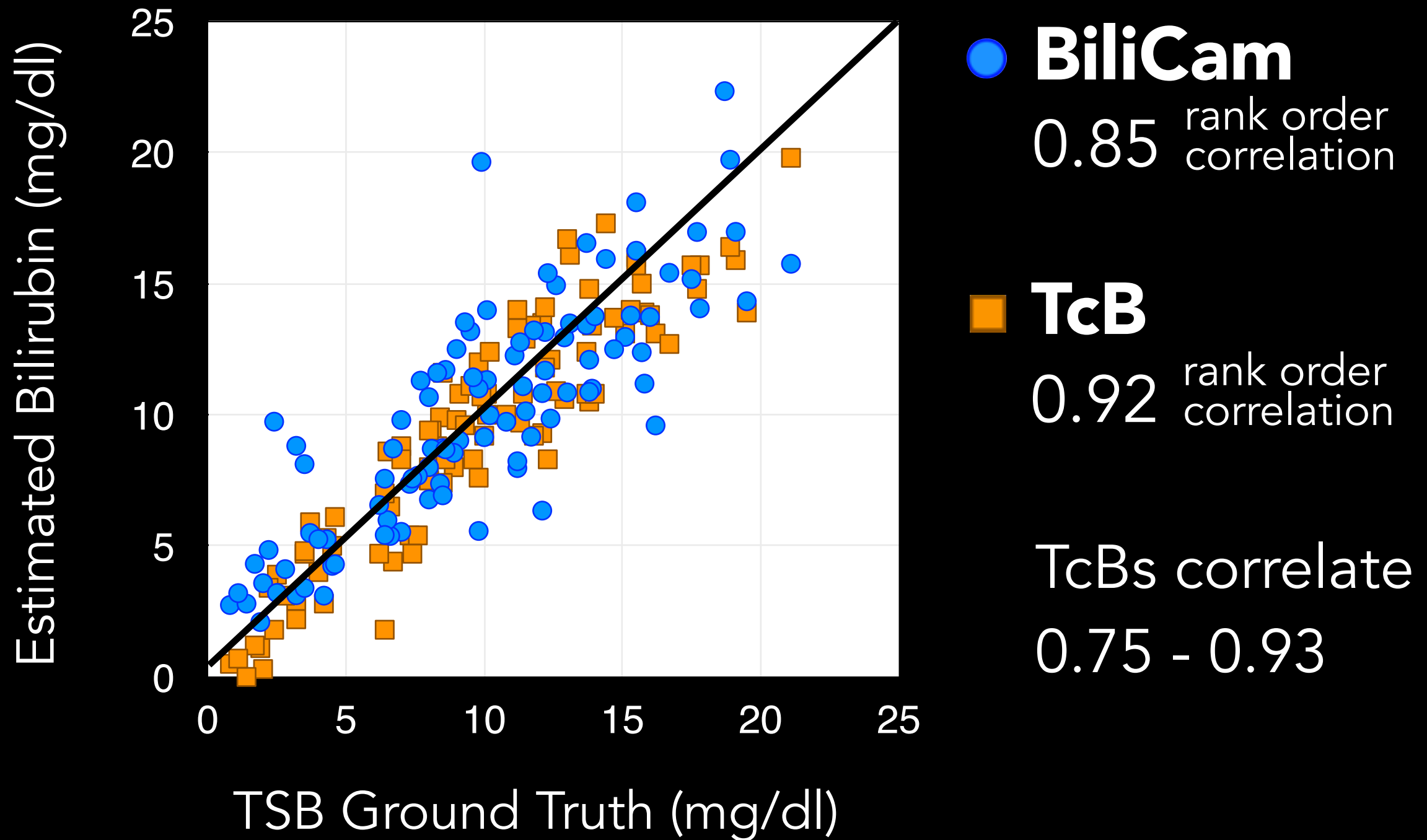


● **BiliCam**
0.85 rank order correlation

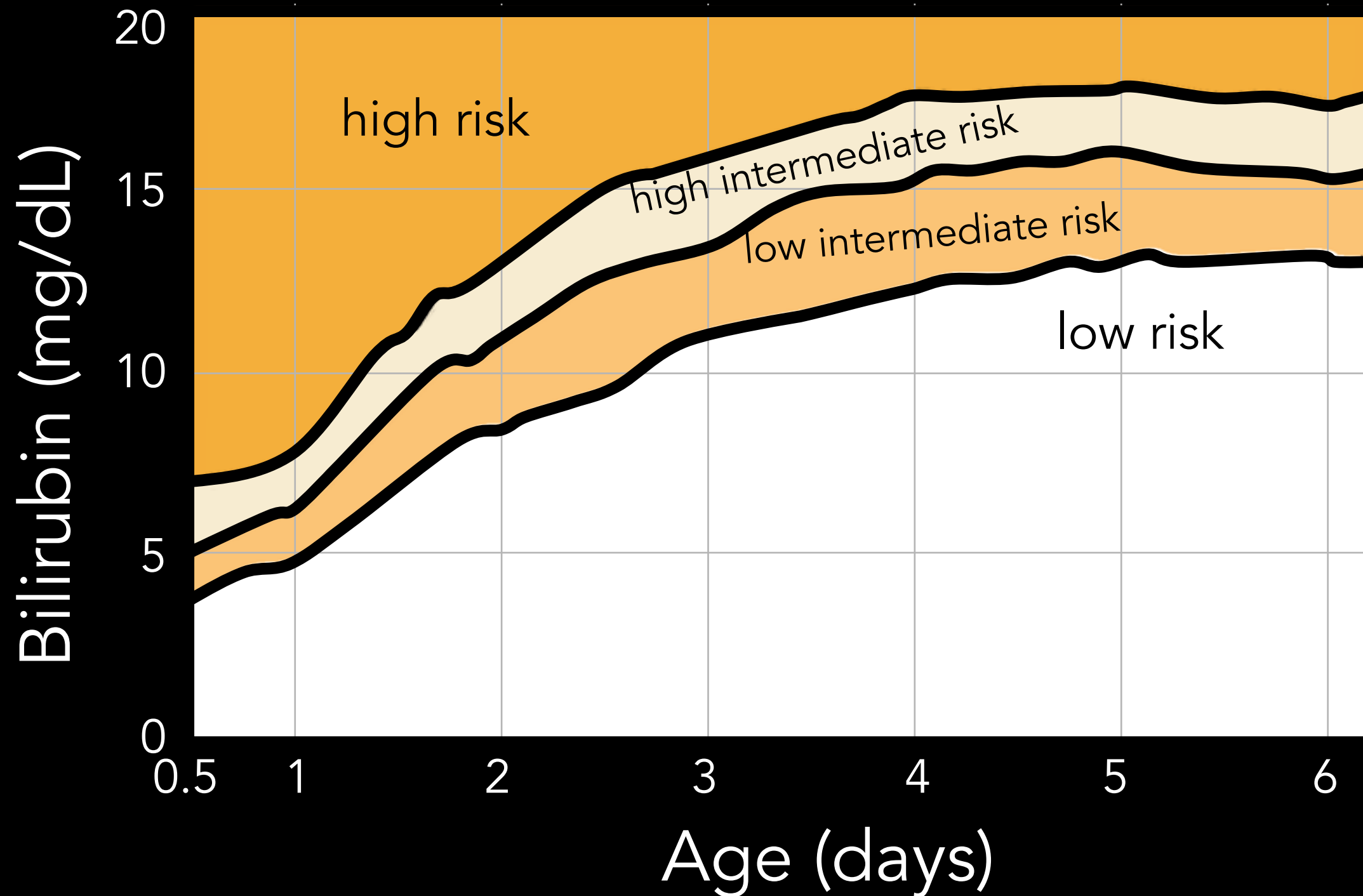
Flash & no flash images

Baselines made no difference

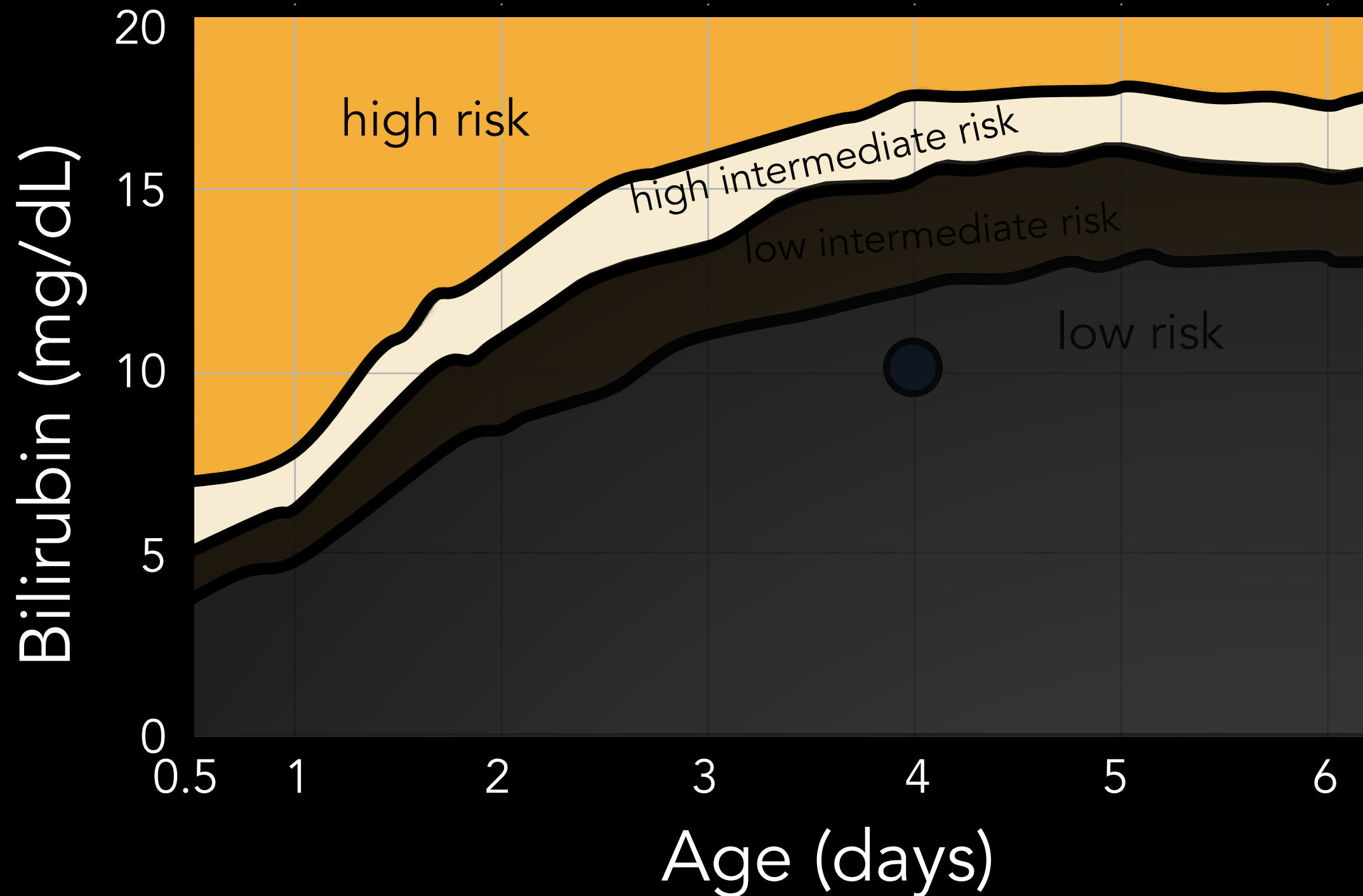
Results



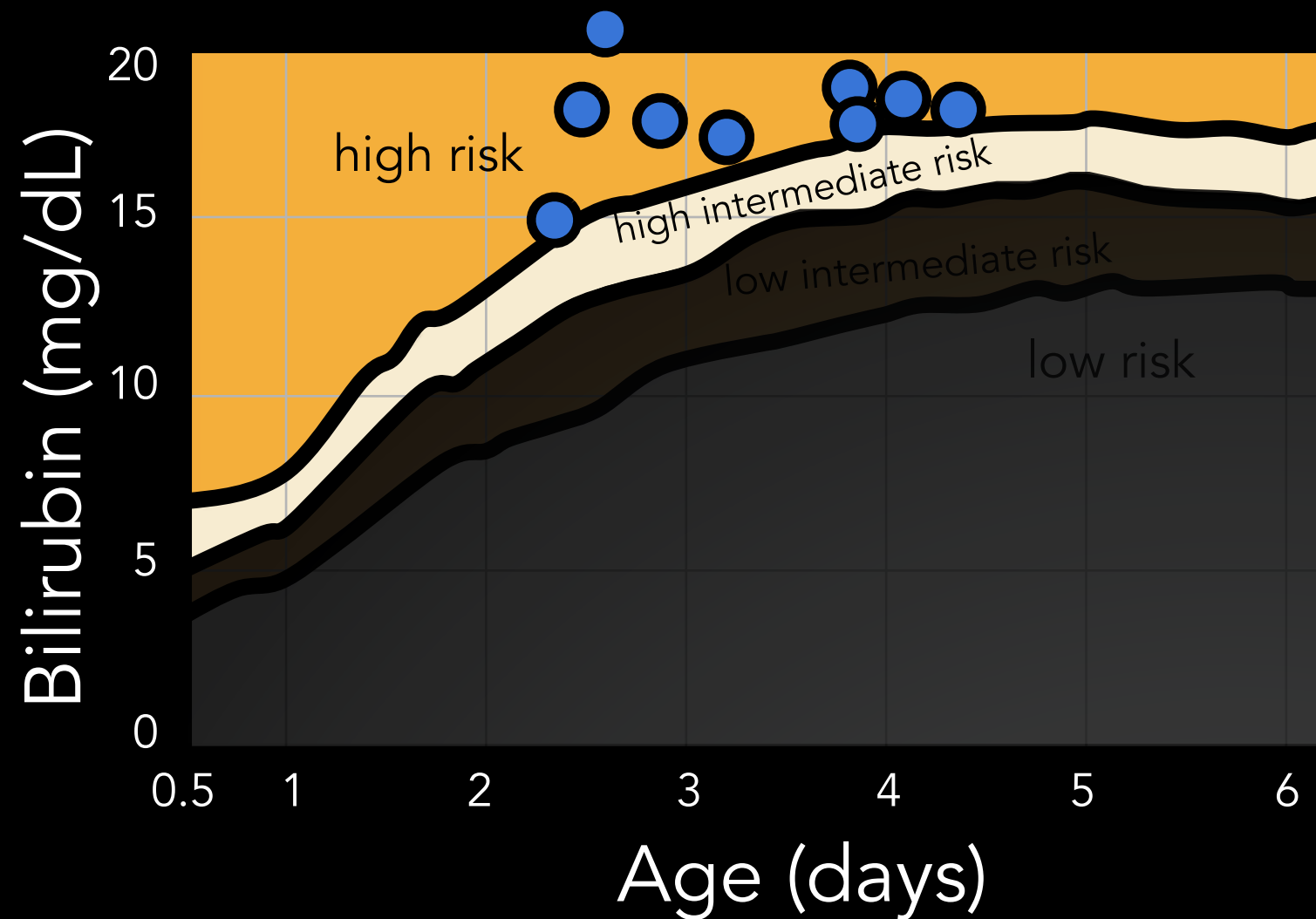
Interpretation



Bhutani Nomogram

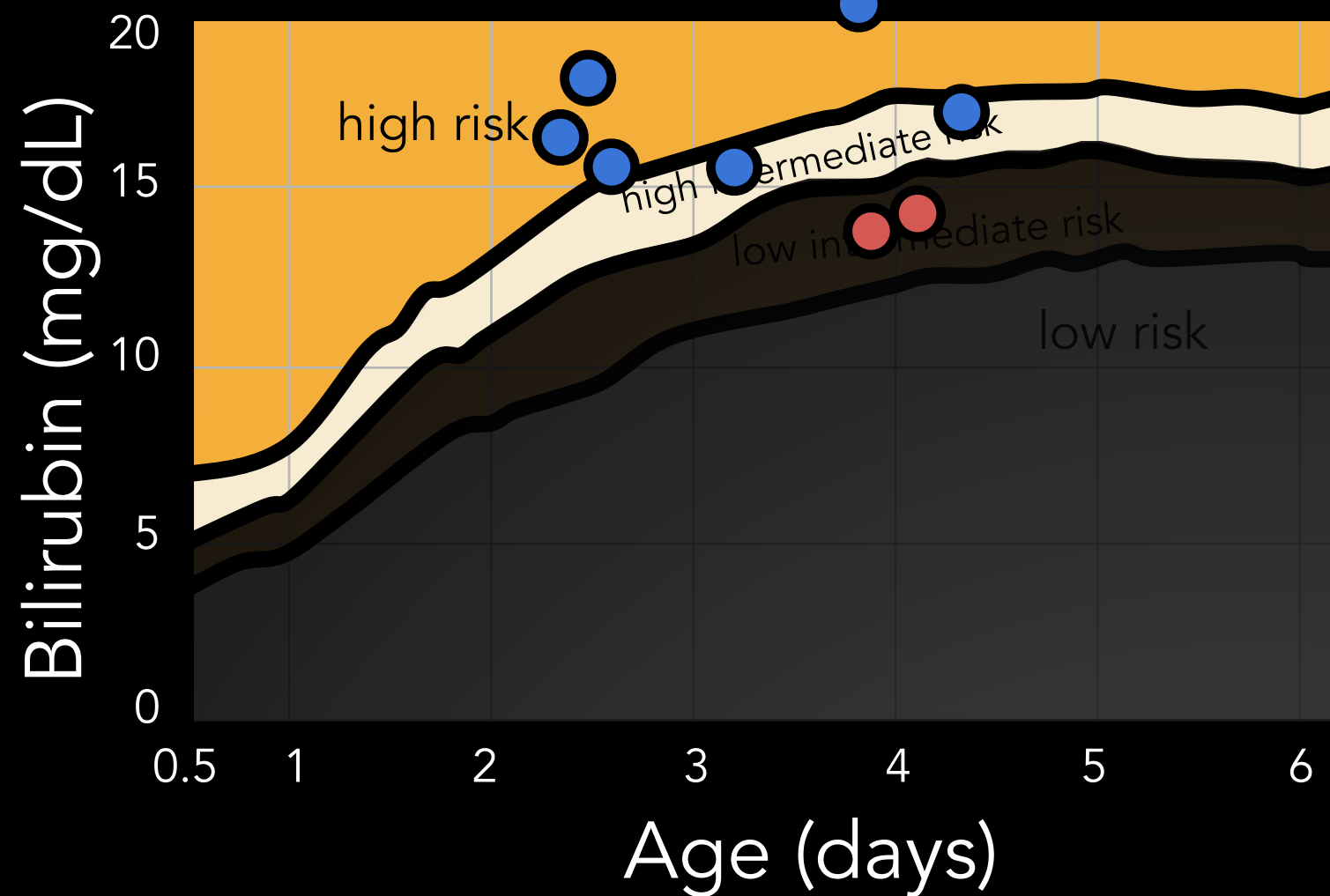


Interpretation



9 high risk cases
based on TSB

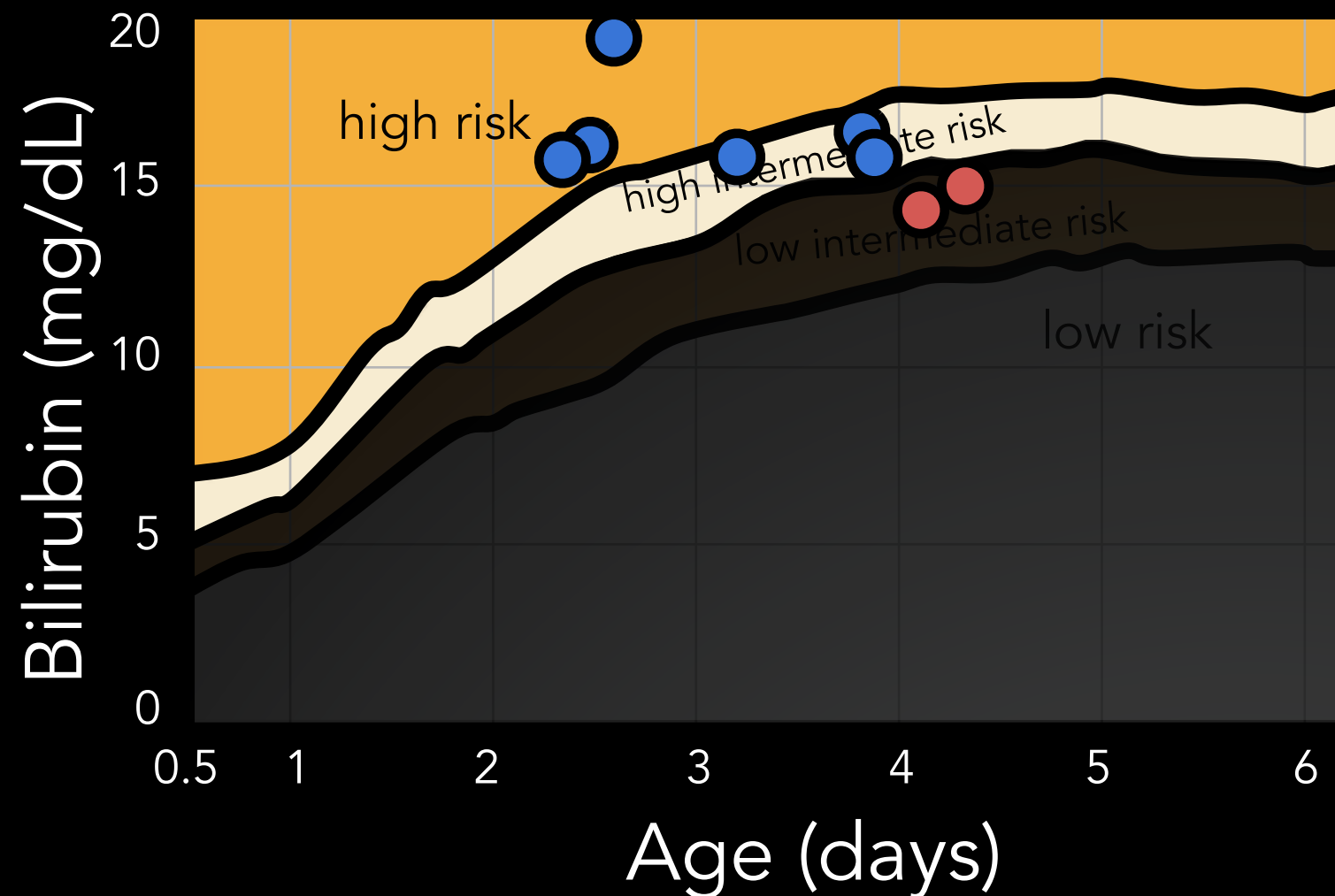
Interpretation



BiliCam

2/9 missed high risk (22%)
85% blood draws avoided

Interpretation



BiliCam

2/9 missed high risk (22%)
85% blood draws avoided

TcB

2/8 missed high risk (25%)
88% blood draws avoided

Limitations & Future Work

Narrow demographic

- 100 newborns
- in Seattle
- 59% white
- limited data with dark skin

More studies
worldwide



Limitations & Future Work

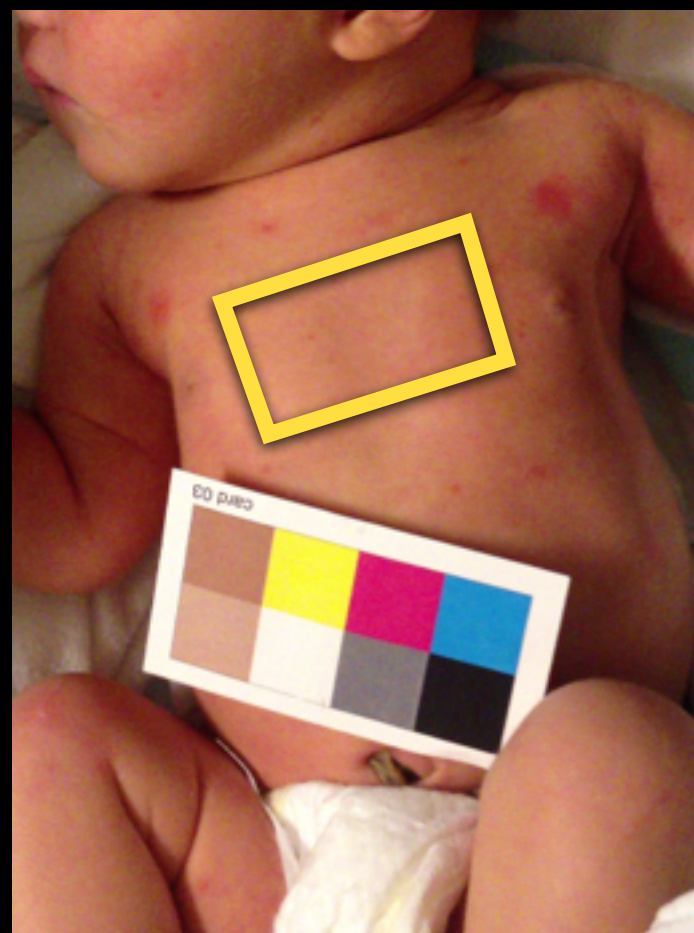
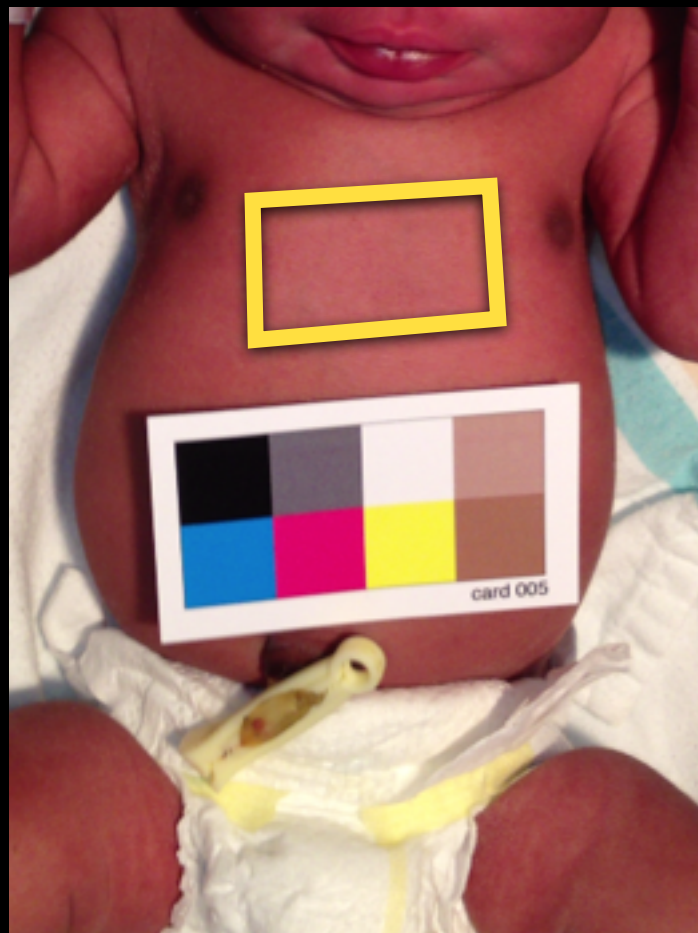
iPhone 4S only

Investigate other phones

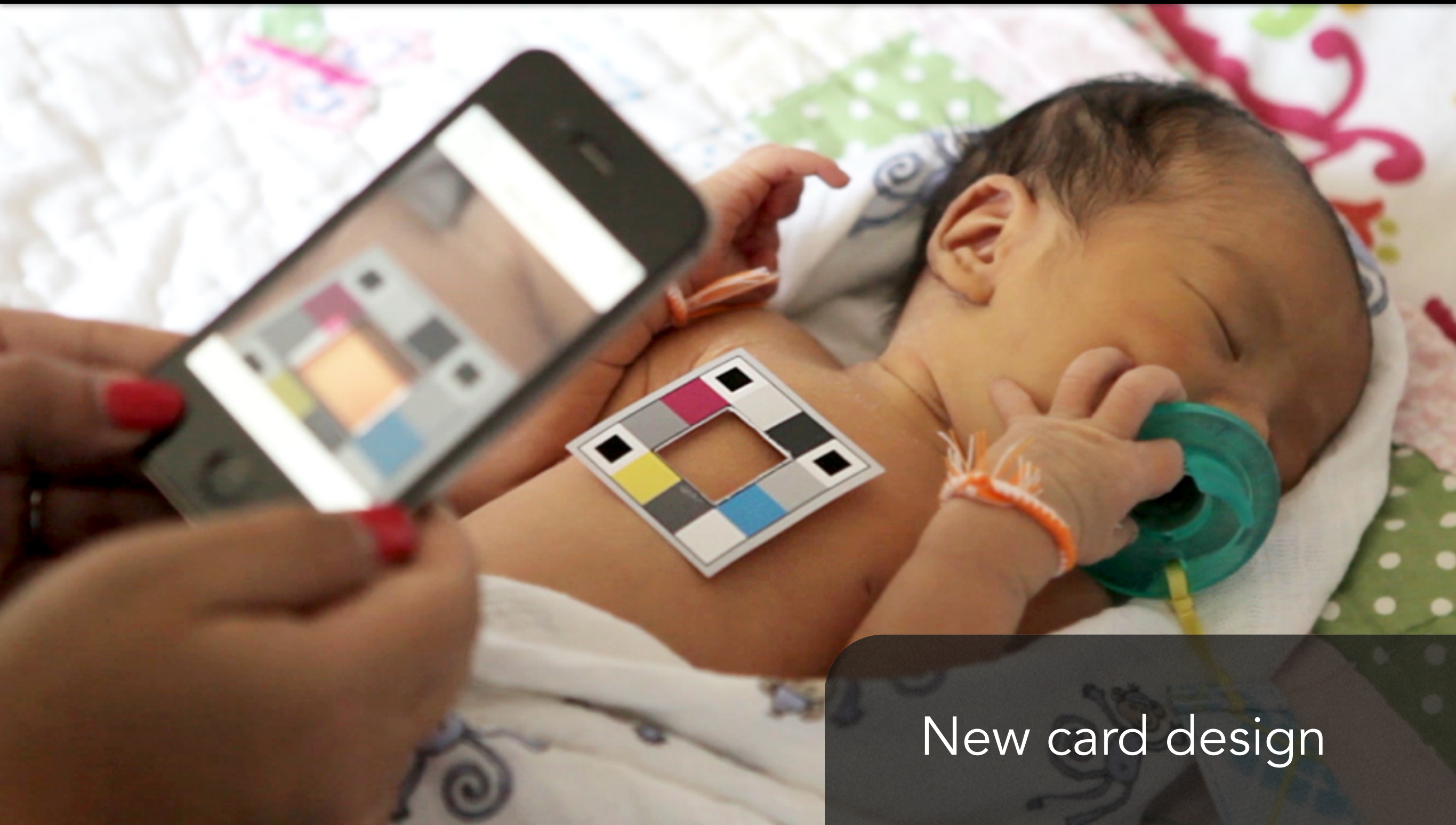


Limitations & Future Work

Good skin segmentation unclear
with current card design



Limitations & Future Work



New card design

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Lilian de Greef ldegreef@uw.edu

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BiliCam

Conclusion



Can be effective
in-home screening tool

Estimates bilirubin
comparably to TcB

Accessible, portable, low-cost

Kernicterus Statistics

In the US



Kernicterus:
21 (\$8 mill)

Hazardous
jaundice: 1158
(\$50,000)

Extreme jaundice:
2,317 (\$20,000)

Severe jaundice: 35,000
(\$8,500)

Phototherapy: 290,000 (\$1,000)

Visible jaundice: 3.5 million

Births/year: 4.1 million

Middle- & low-income
countries:

- 75,000 cases kernicterus/year
- 114,000 newborn deaths/year
- 65% newborn deaths from kernicterus

Study Demographics

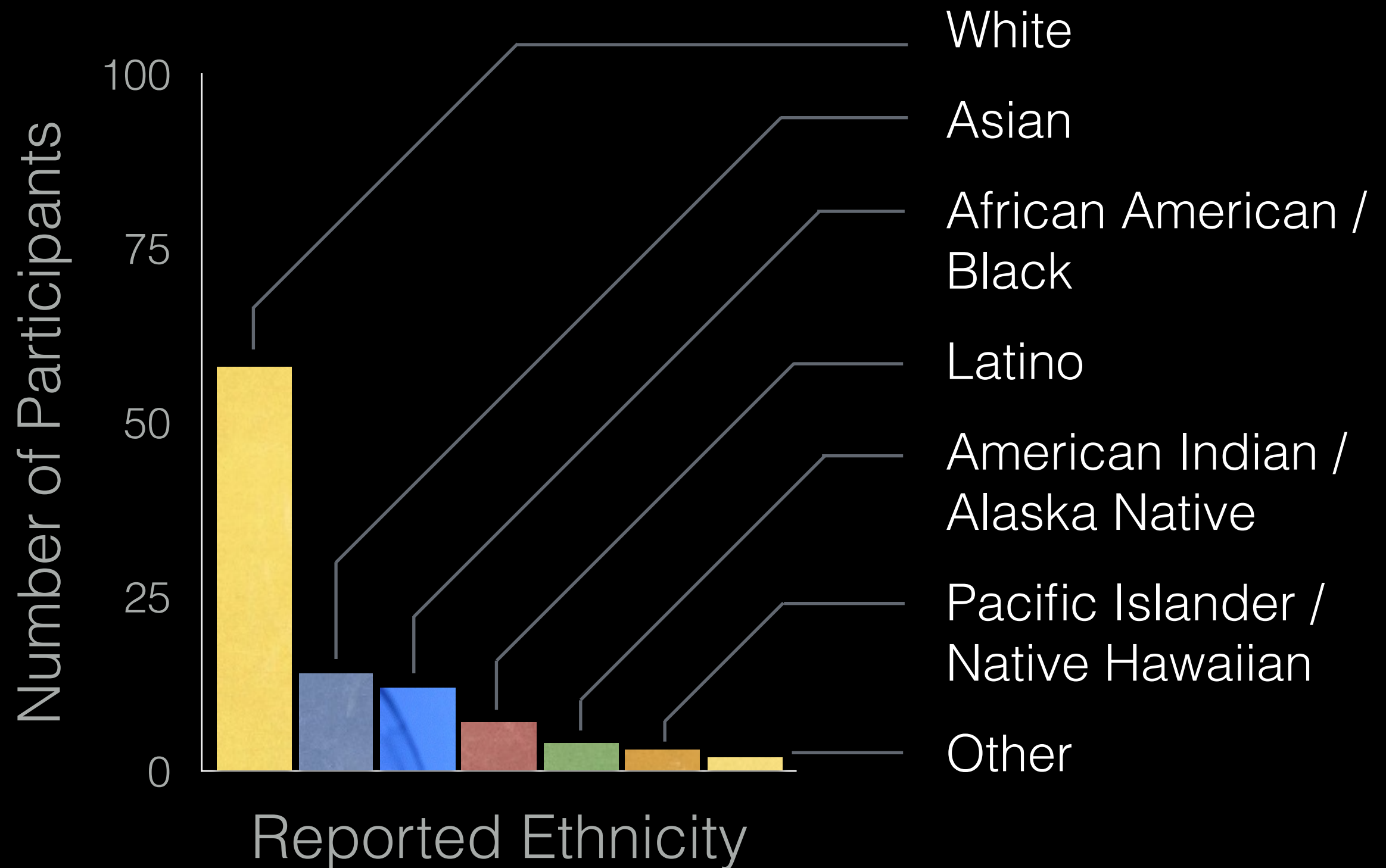
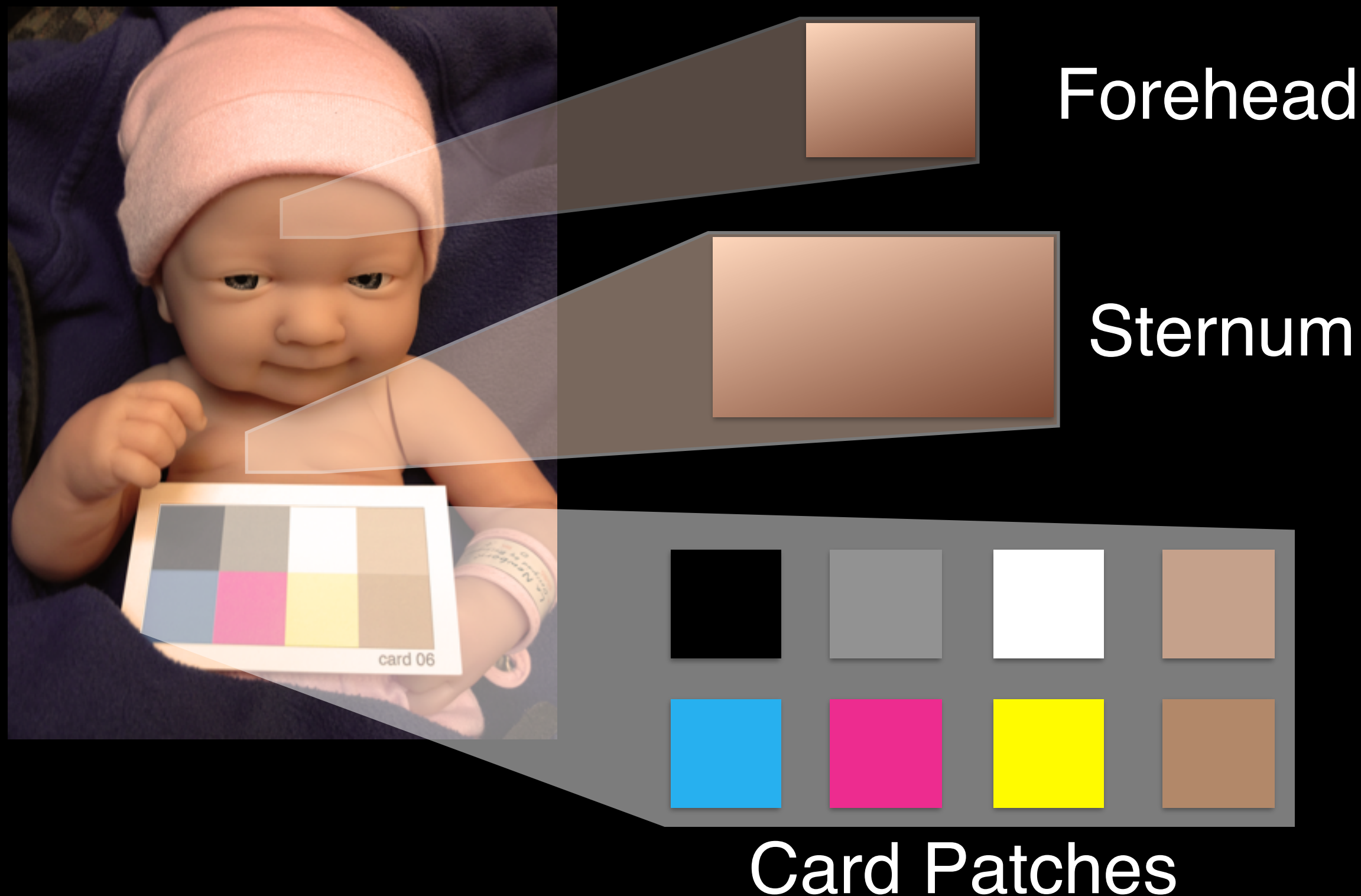
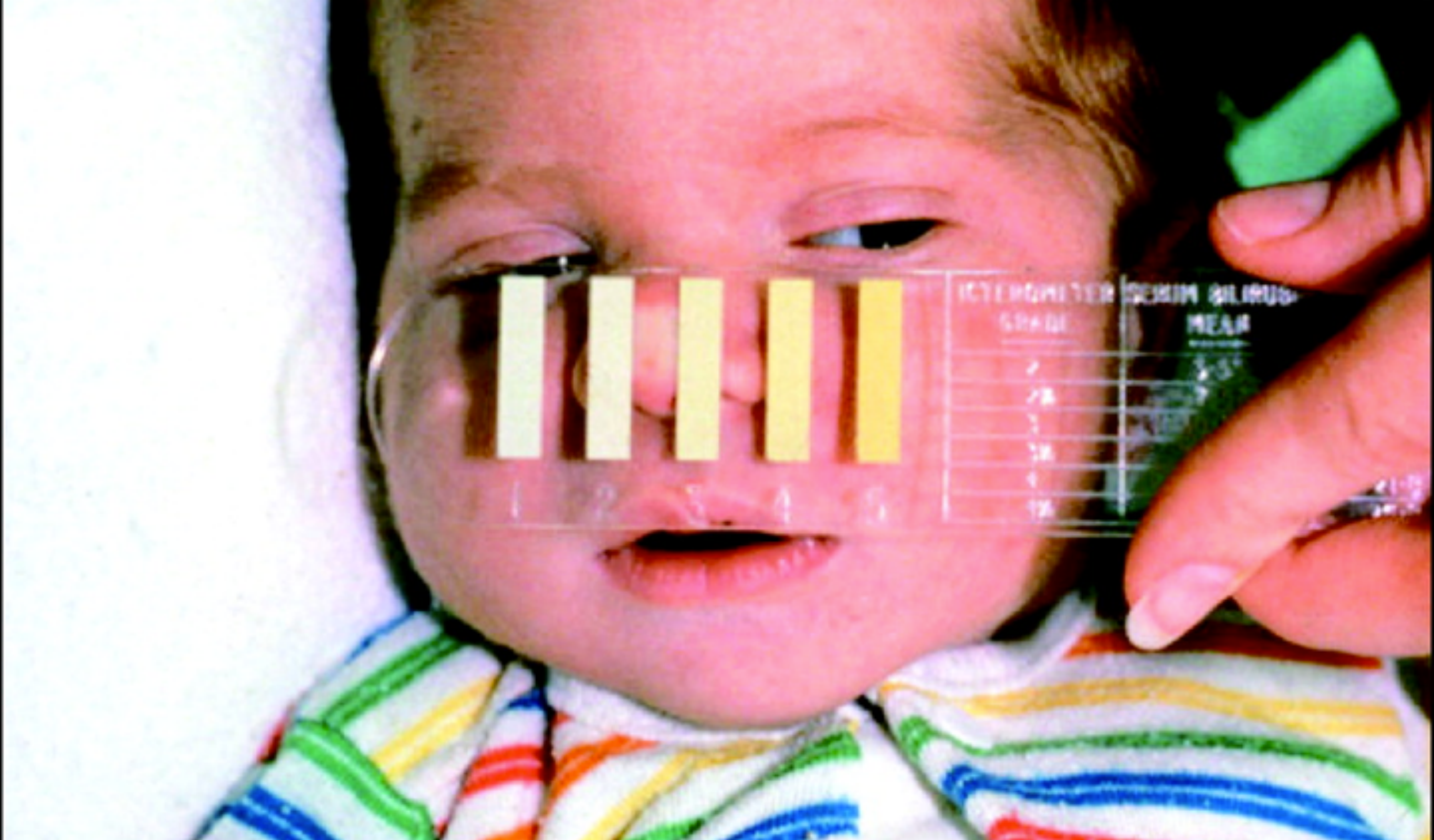


Image Segments





Icterometer