

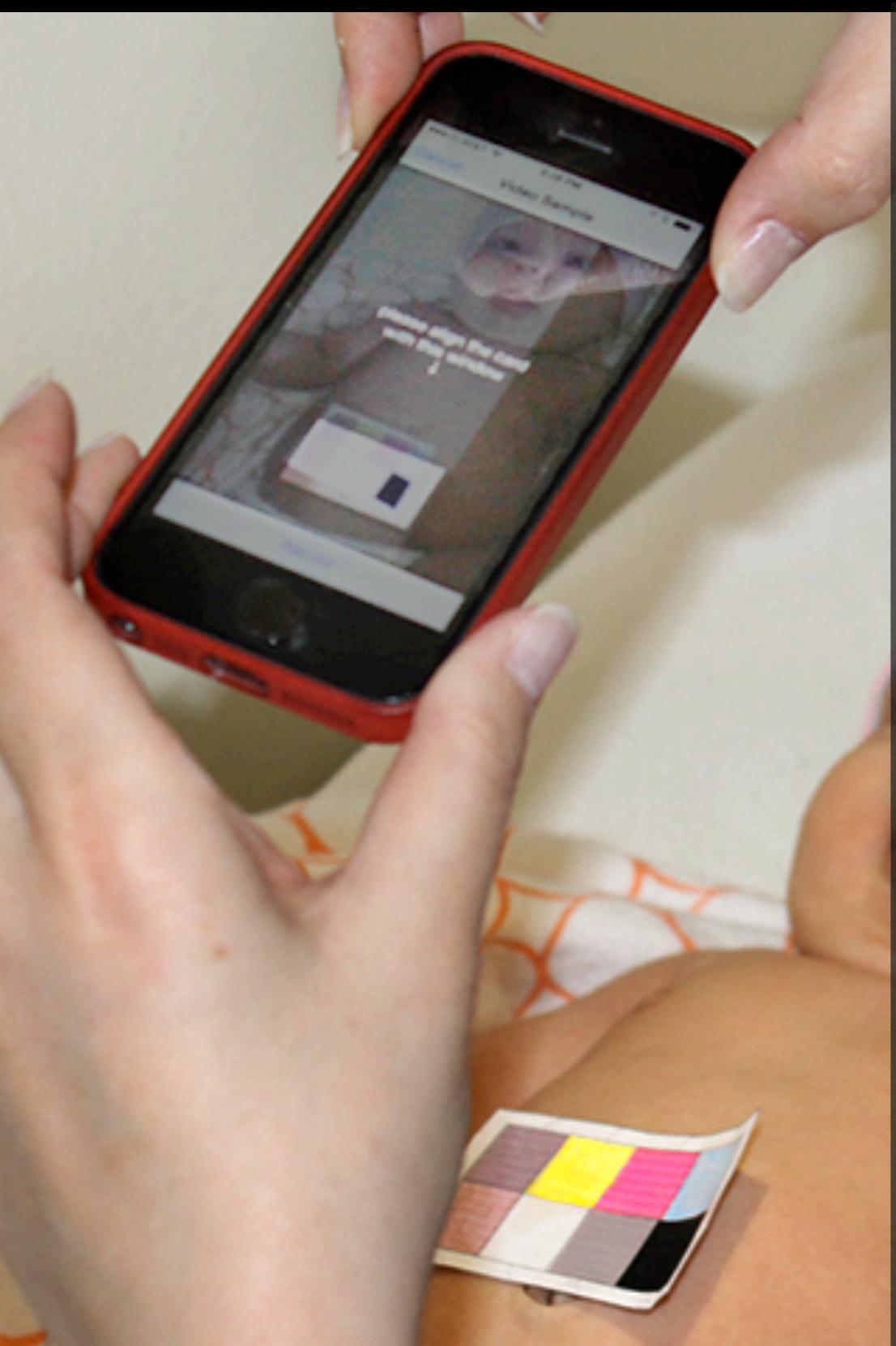
BiliCam: Using Mobile Phones to Monitor Newborn Jaundice



Lilian de Greef, Mayank Goel, Min Joon Seo,
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James A. Taylor MD, Shwetak N. Patel

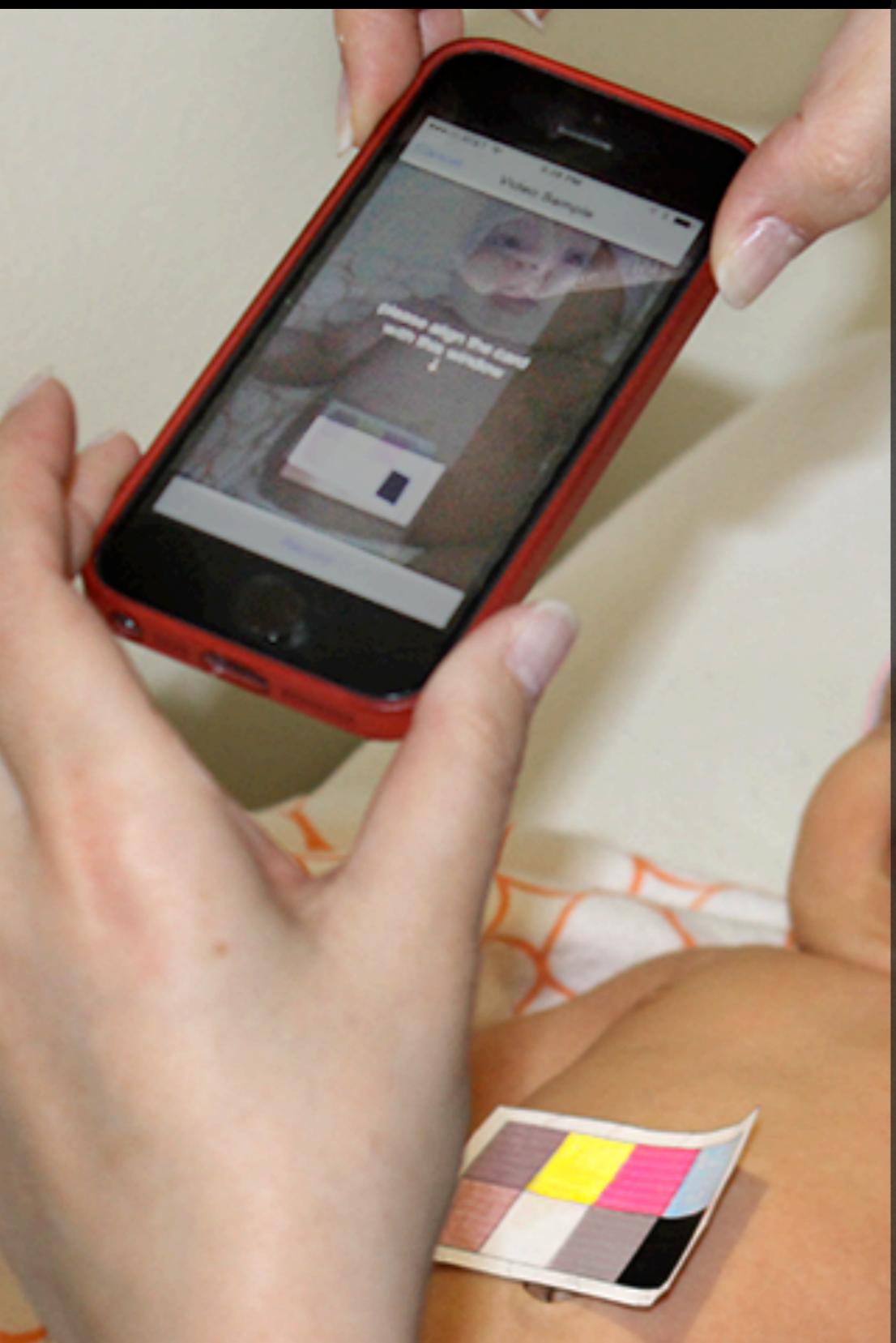


What is BiliCam?



A smartphone-based system
to assess newborn jaundice.

Overview



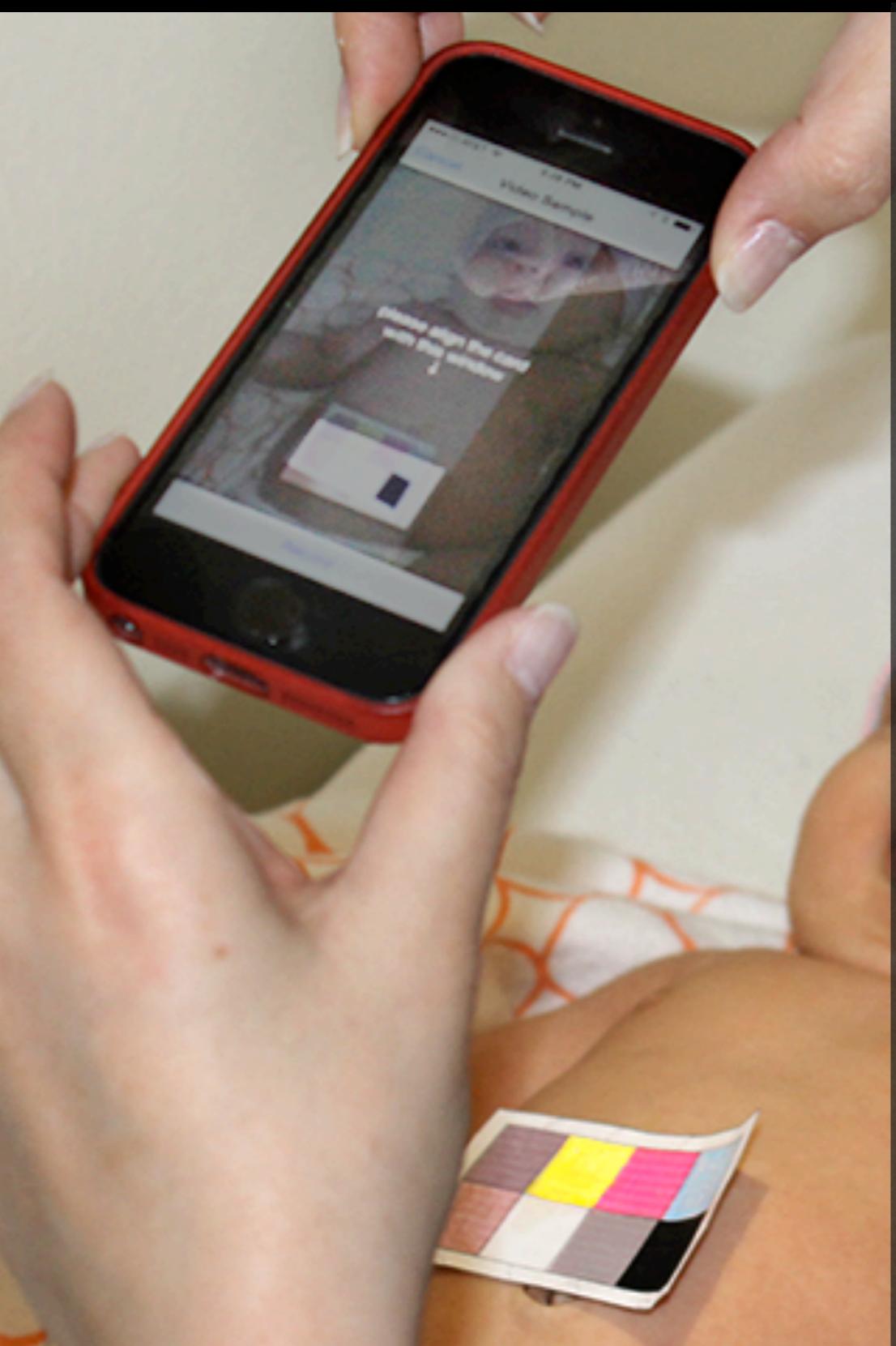
100 newborn
clinical study

Performs similarly to an
FDA approved device

\$7000

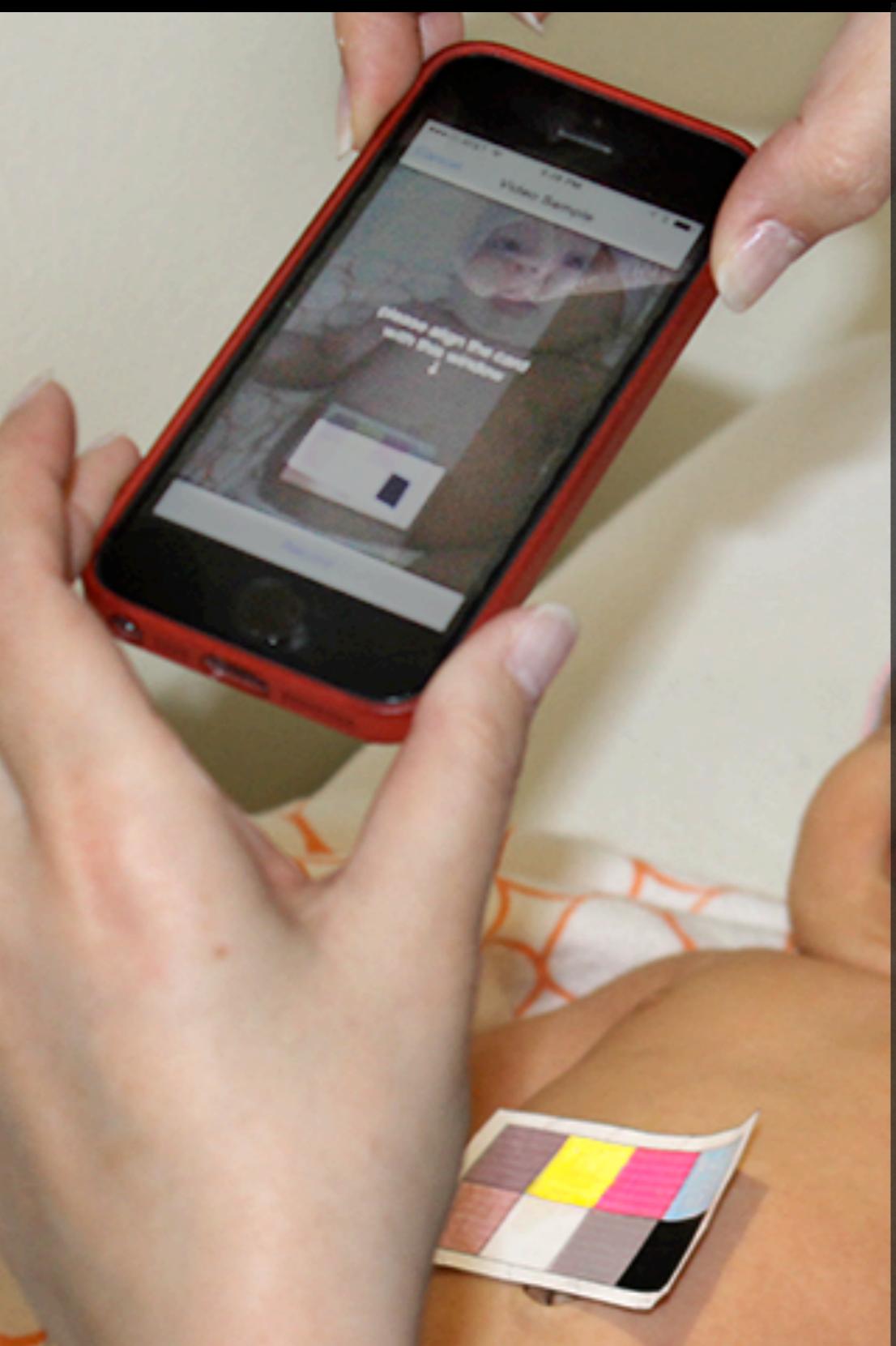


What is BiliCam?



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

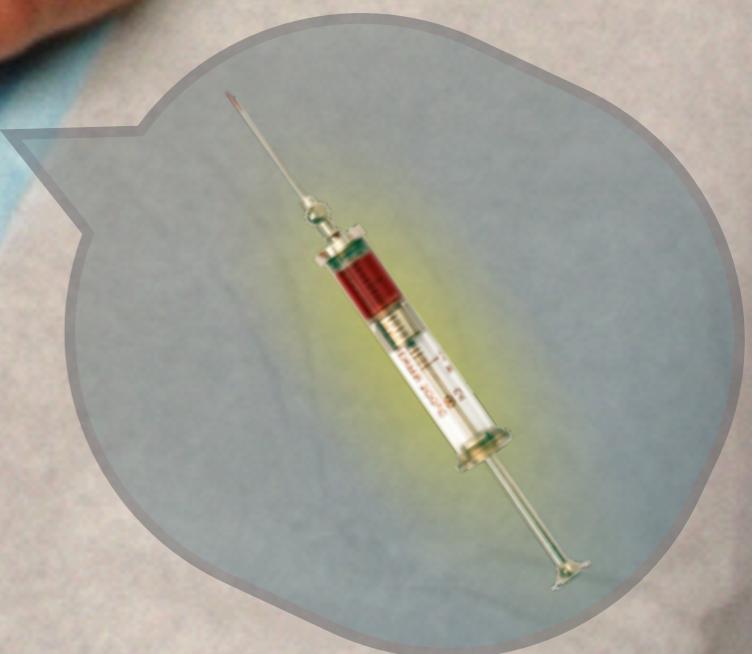
peaks in 3-5 days

84% of all newborns

extreme levels **devastating**



worry







1 in 14 undergo
phototherapy





Screening Method?



С
80
200°C



Total Serum Bilirubin



TSB



Medical Gold Standard



Transcutaneous Bilirubinometer



TCB



TcB

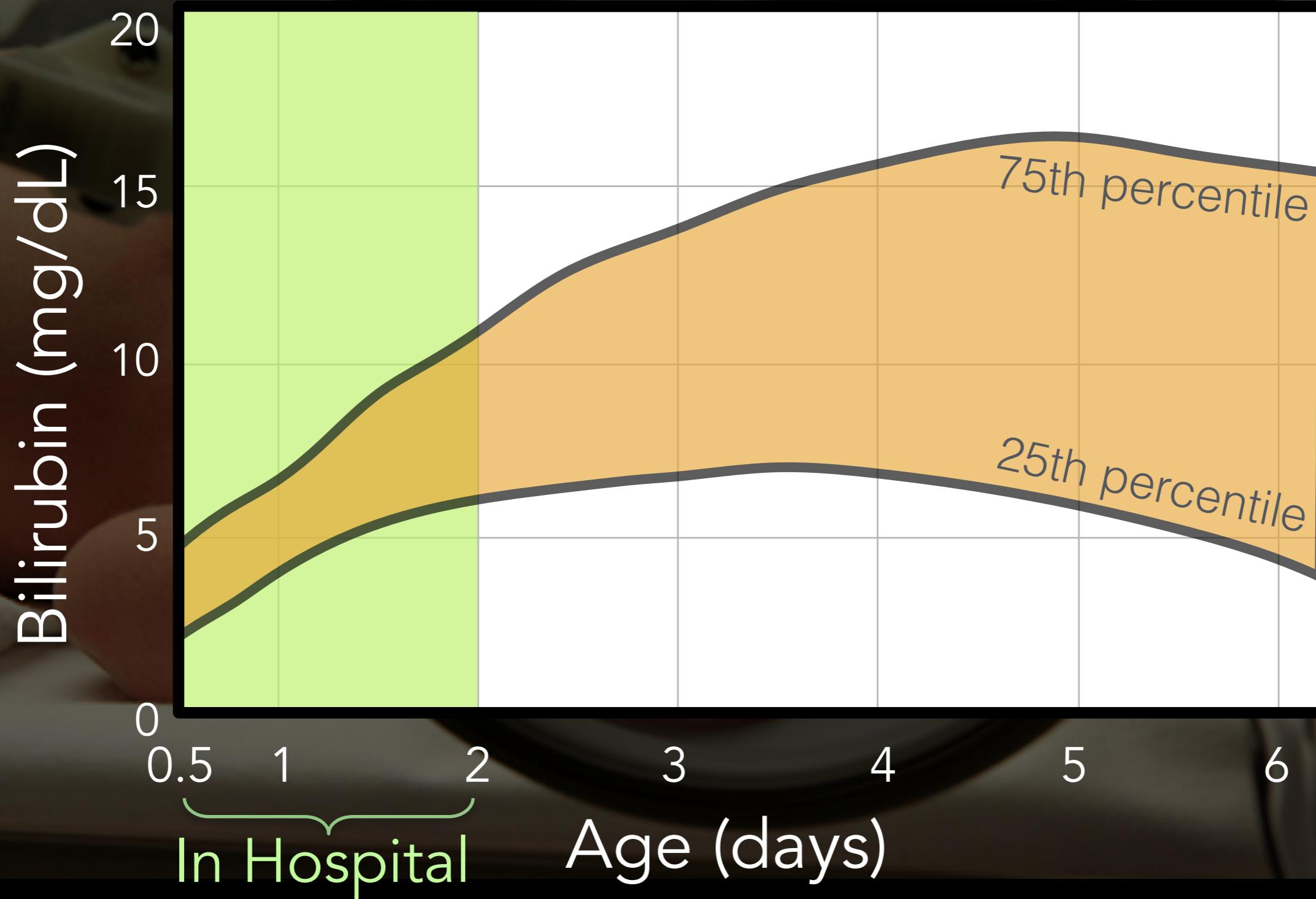


TCB



\$7000
Non-invasive
Quick results
Correlates 0.75-0.93
Screening tool for TSB

Newborn Bilirubin Levels



Screening Challenges

In Hospital



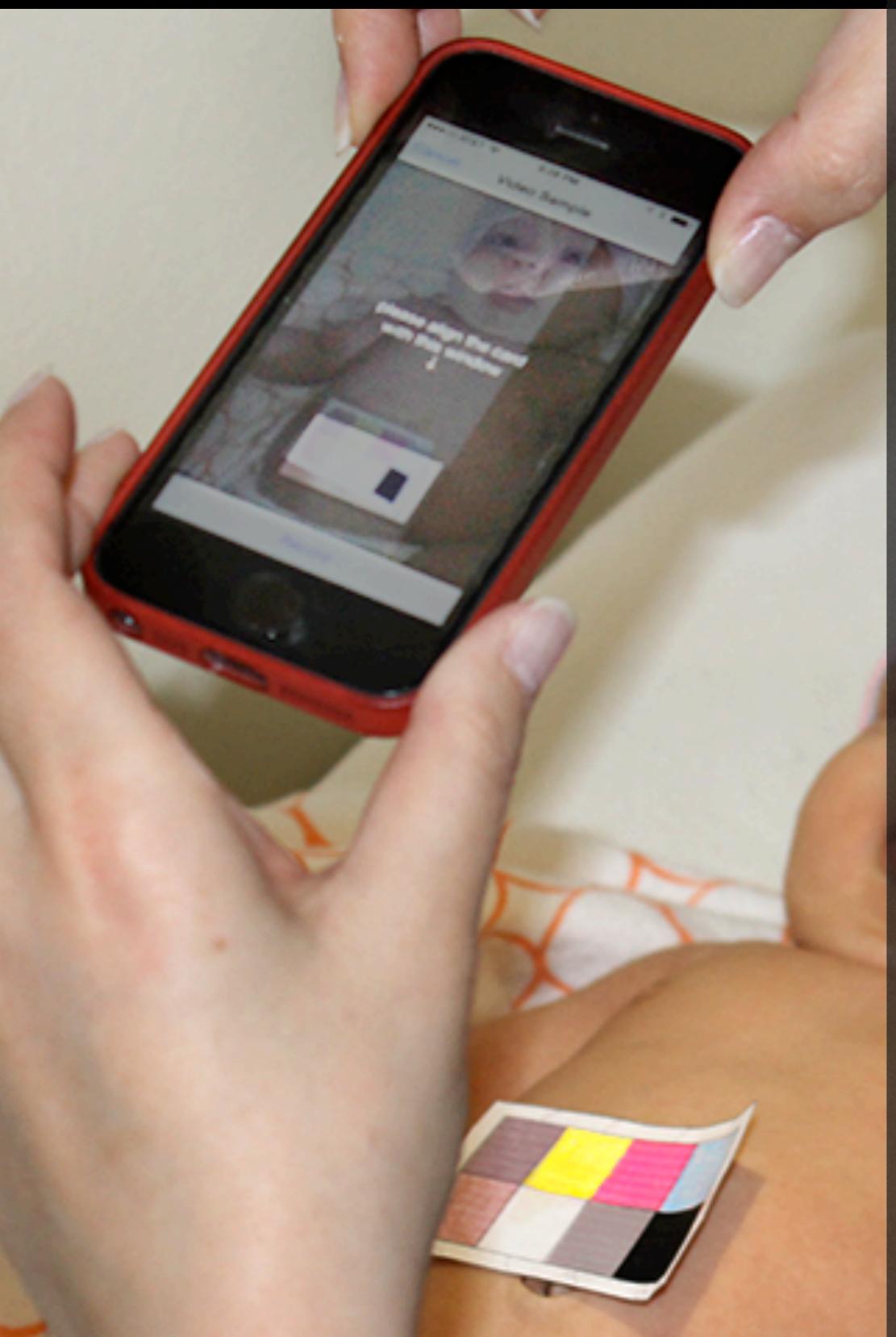
At Home

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

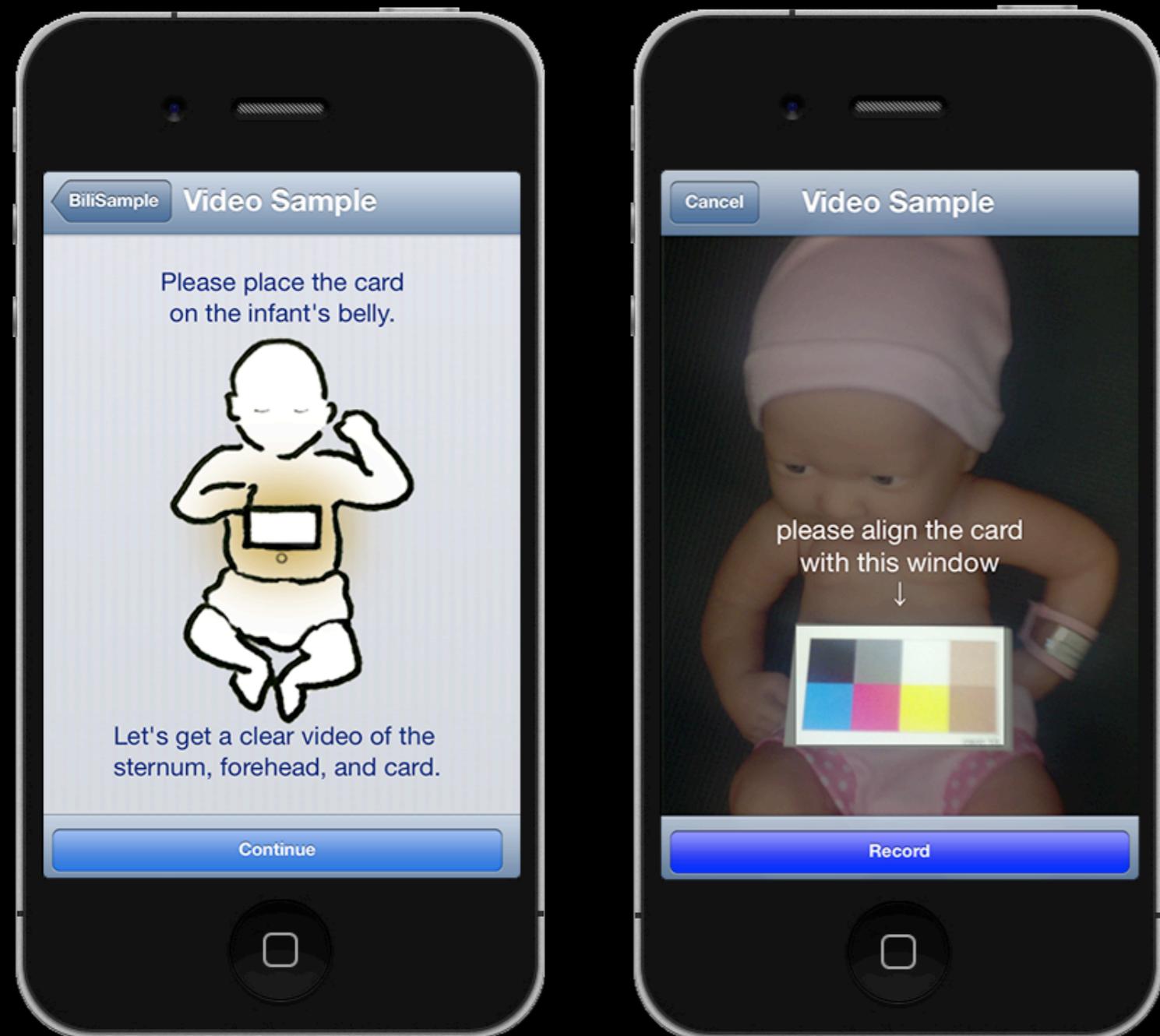
Photos: with &
without flash



TSB (ground truth)

TcB (control)

Data Collection App



Standardize

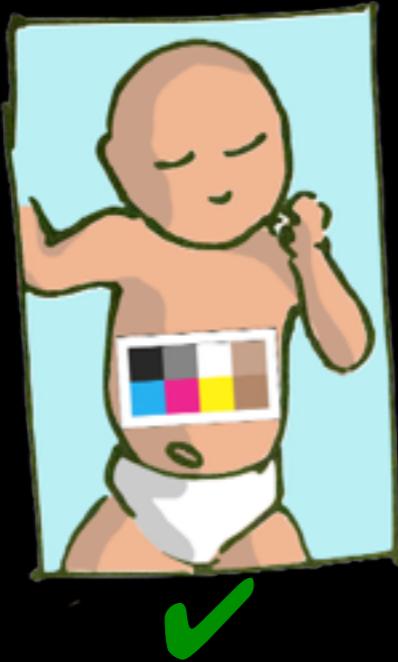
- white balance
- card position
- phone position

Noisy Data



Automatic Quality Control

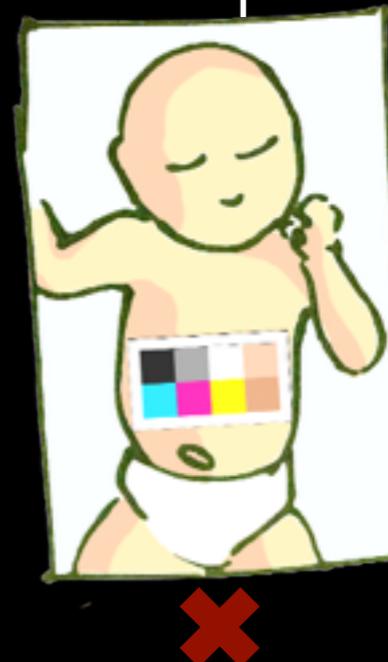
Ideal



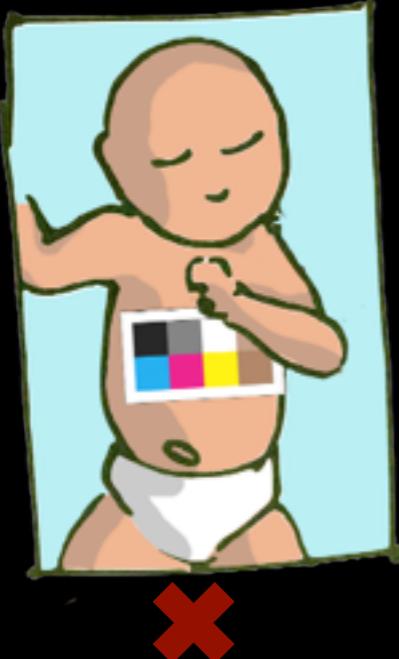
Glare



Overexposed



Occlusion



Shadow



Underexposed



Algorithm Overview



Algorithm Overview



Color Balance



Different lighting conditions

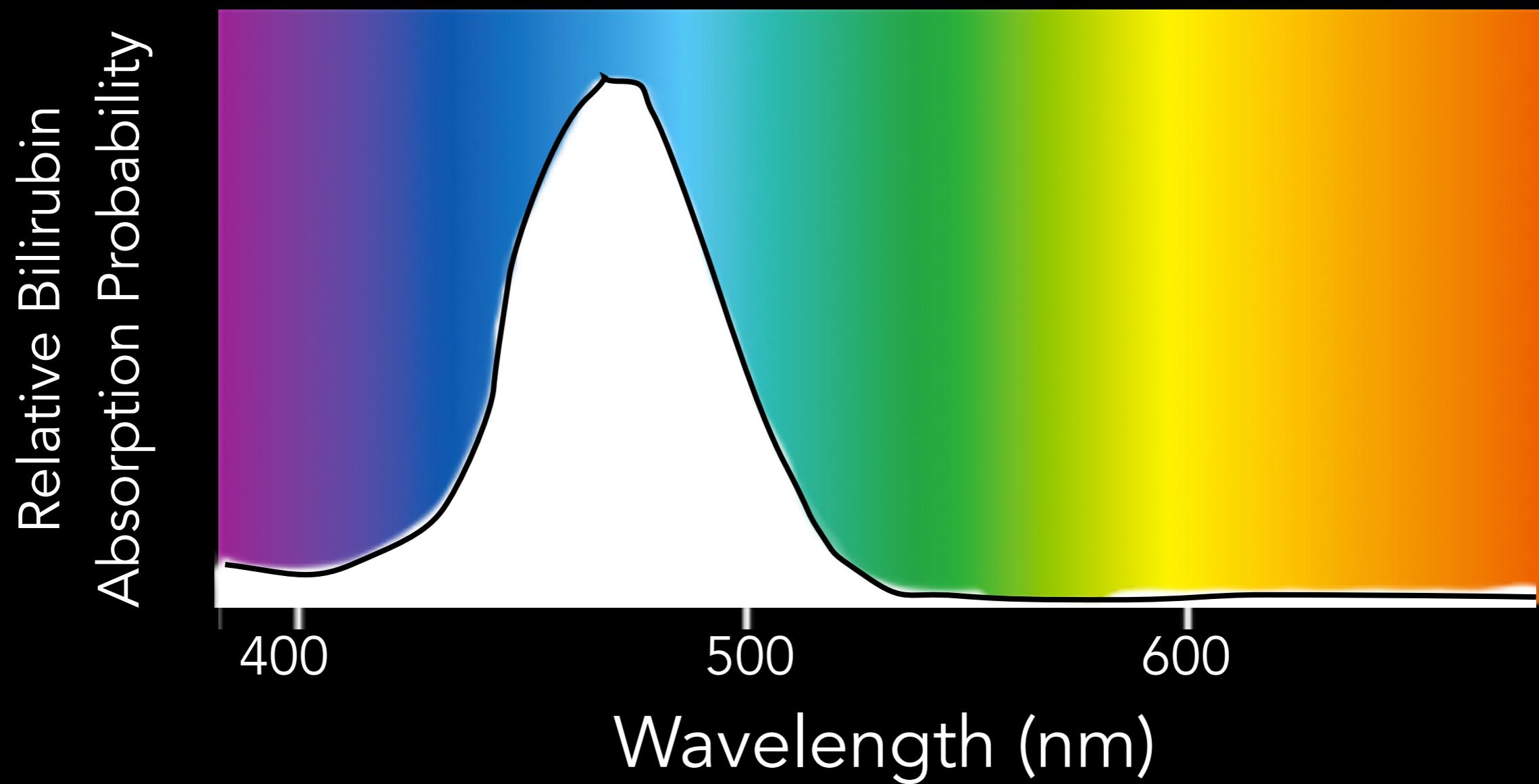
Color Balance



Algorithm Overview



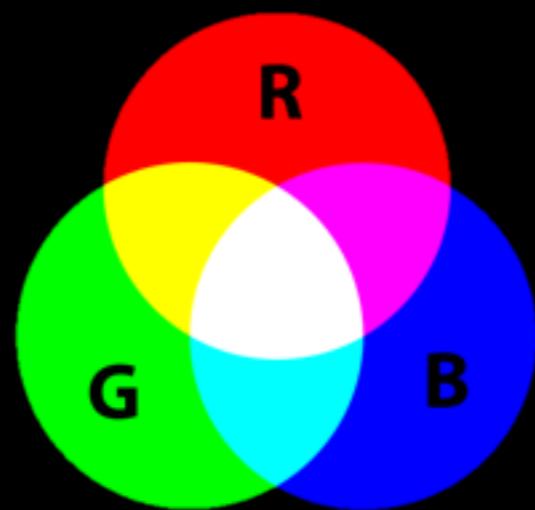
Bilirubin Absorption Properties



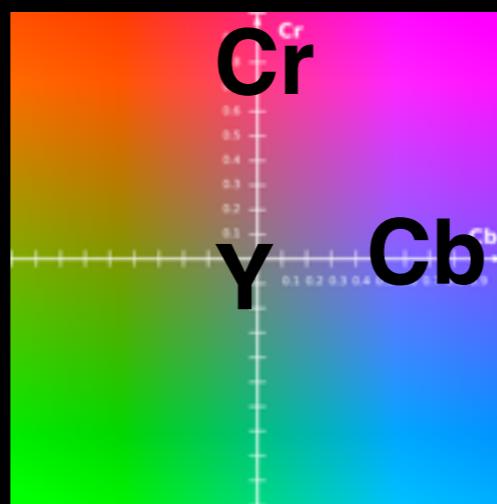
Feature Extraction



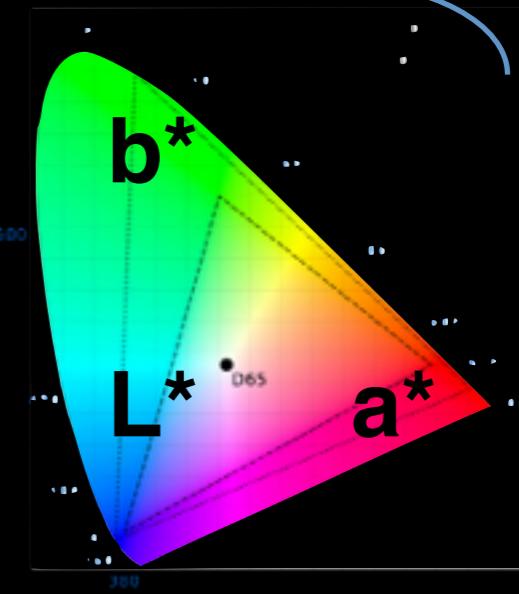
with & without flash



RGB

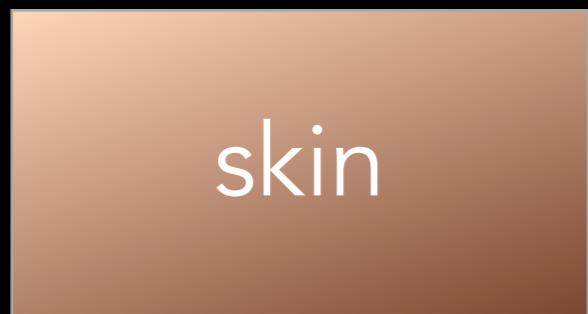


YCbCr



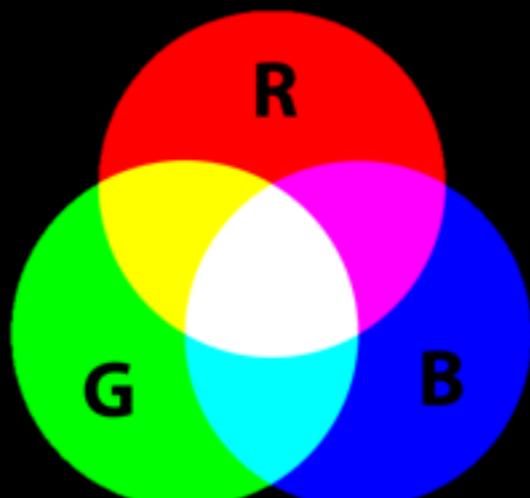
L*a*b*

Feature Extraction

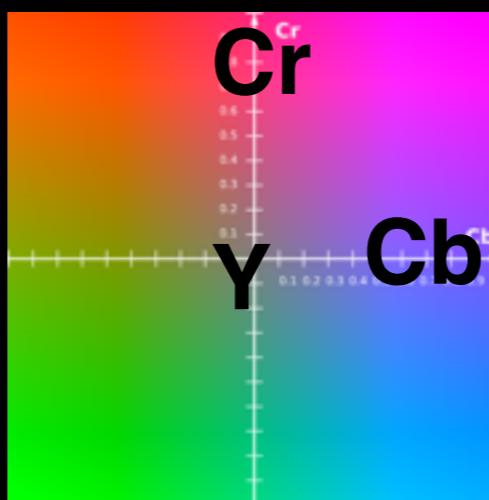


Gradient
(of RGB channels)

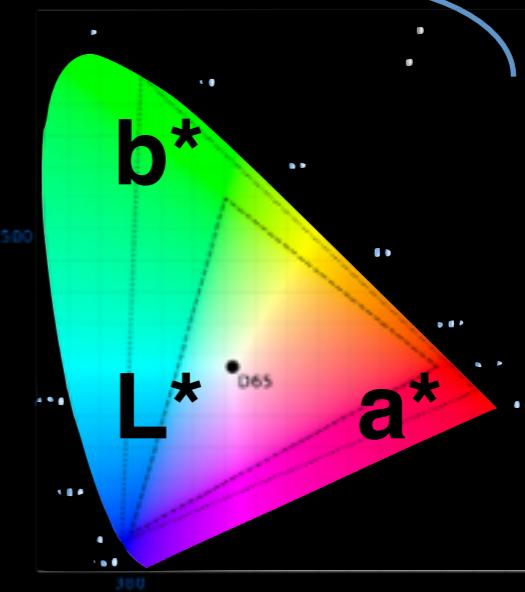
with & without flash



RGB

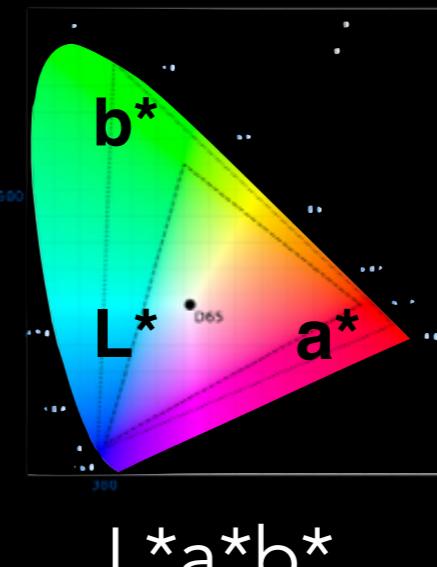
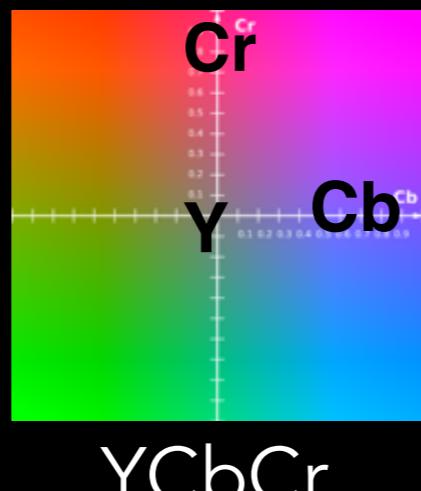
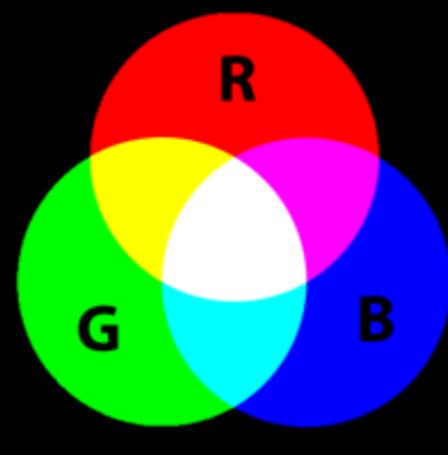


YCbCr



L*a*b*

Feature Extraction



Gradient
(of RGB channels)

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

total: 21 features

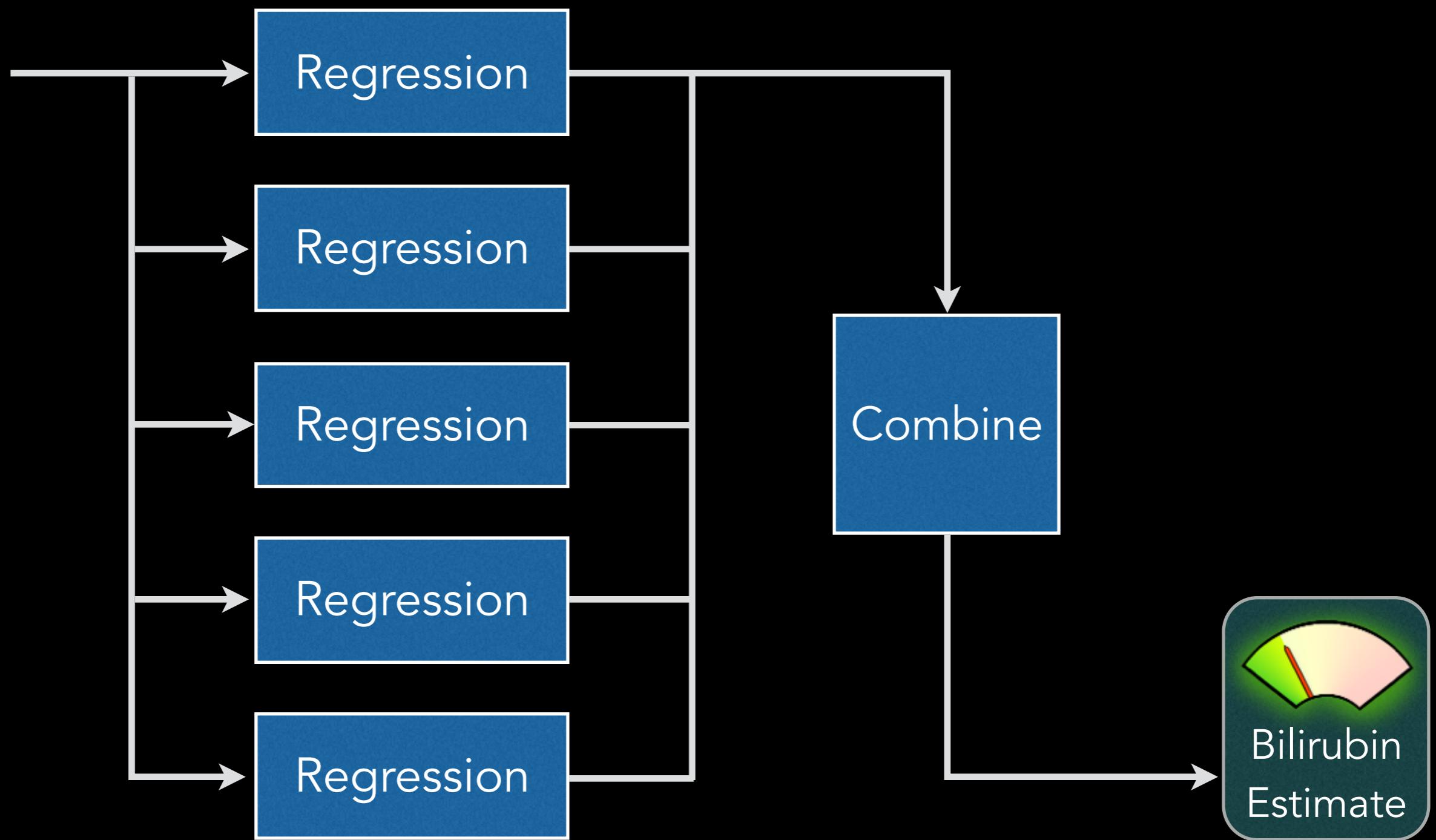
Processing Features

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

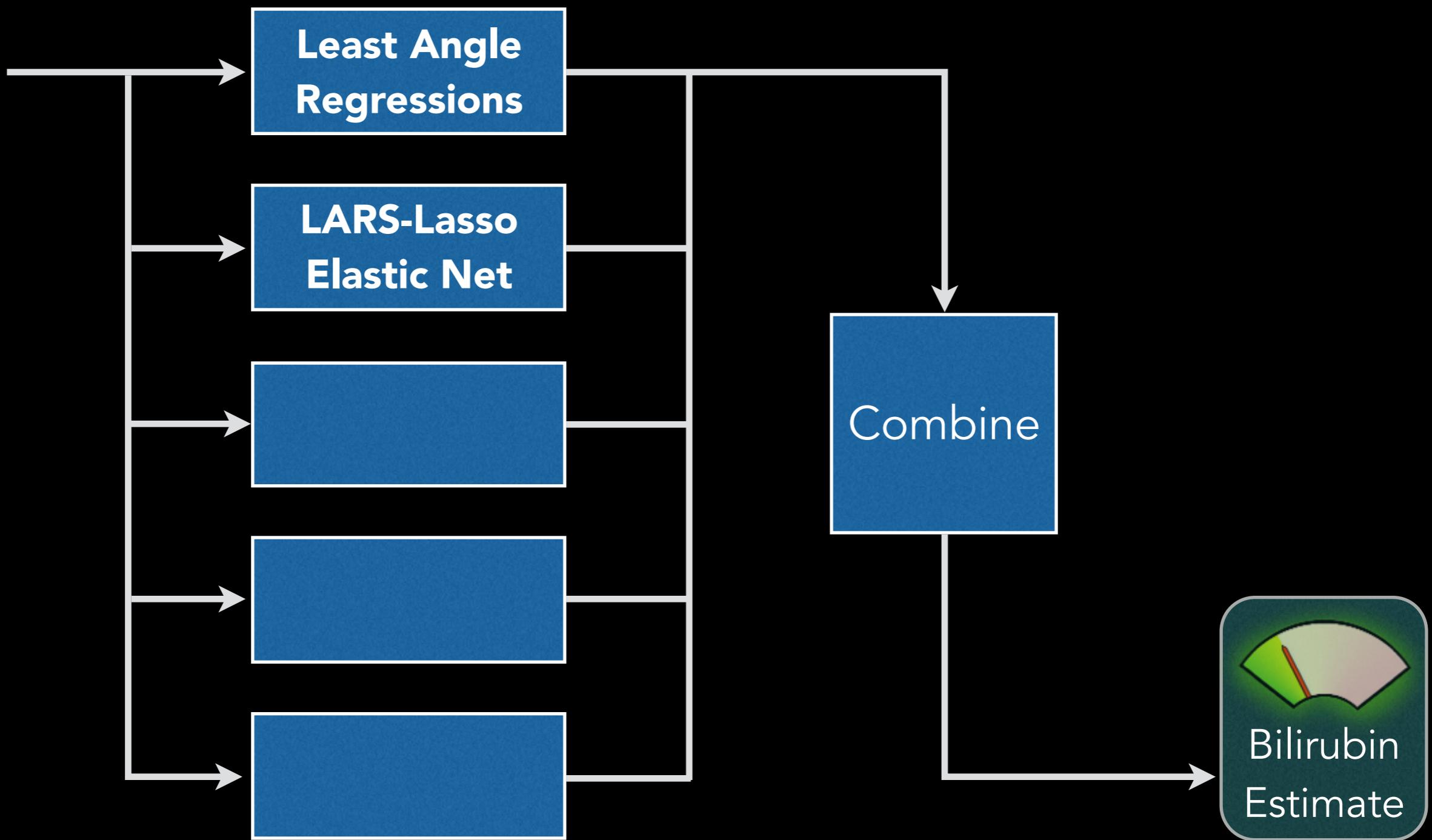
Algorithm Overview



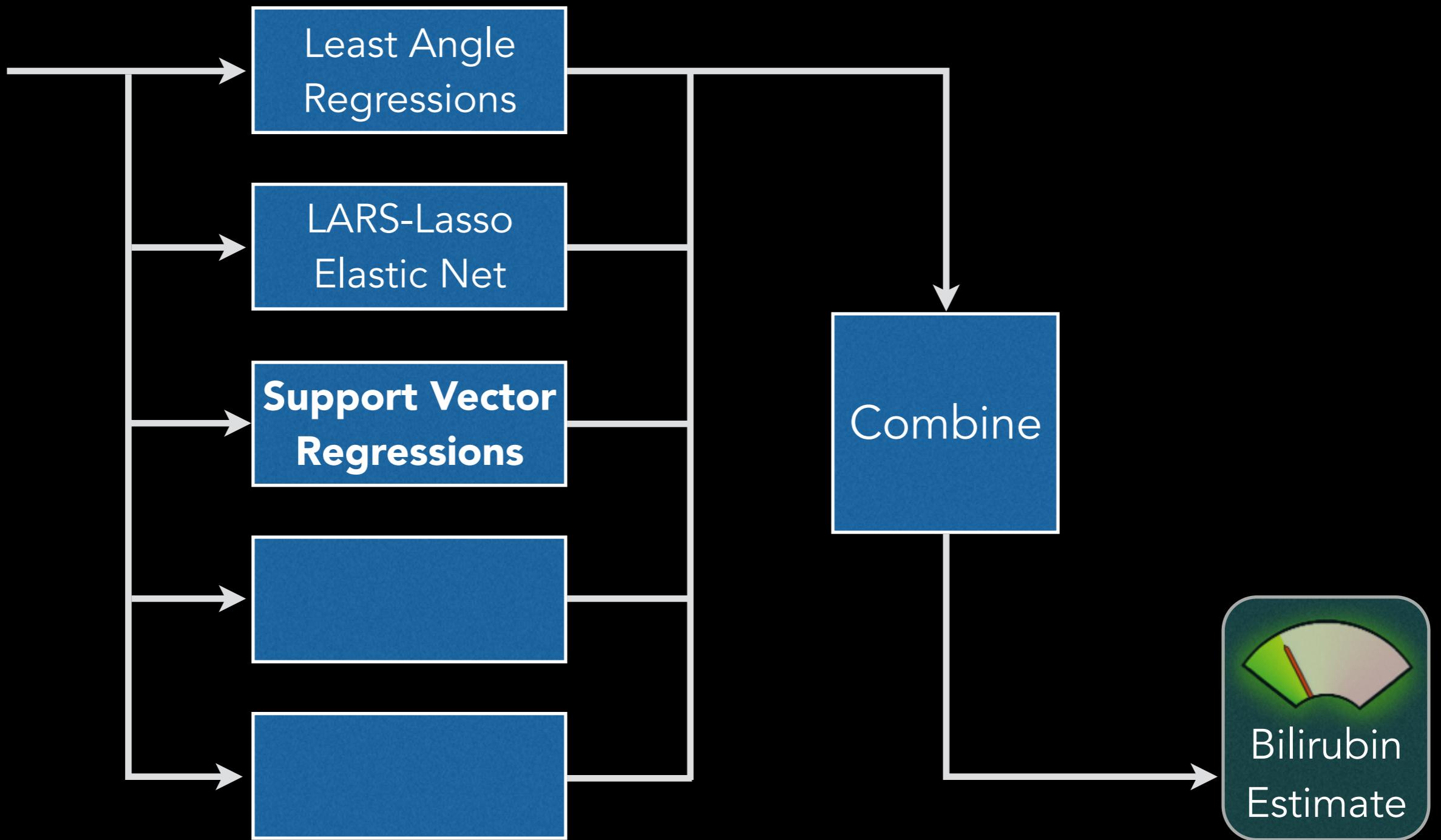
Regression Ensemble



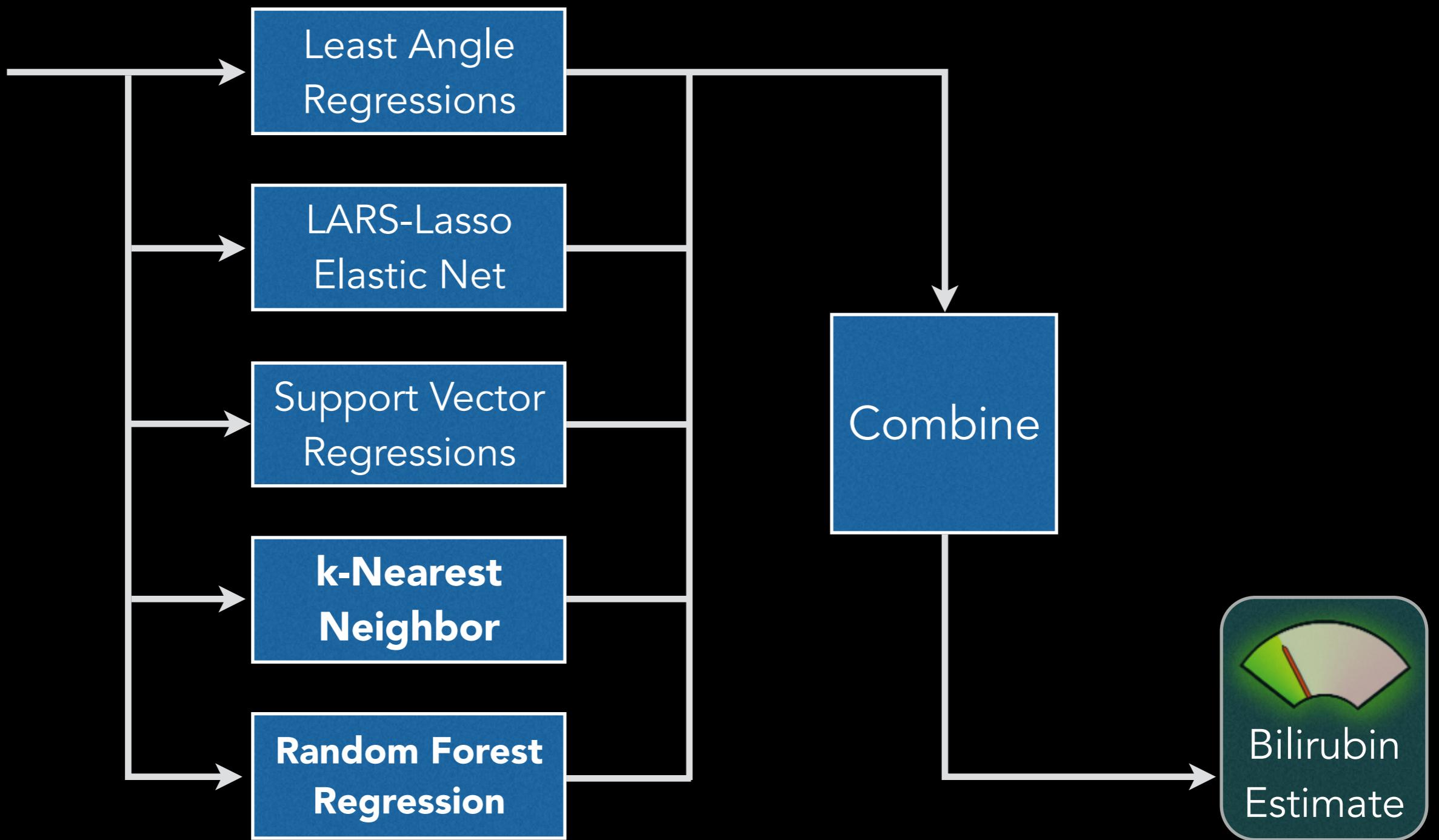
Regression Ensemble



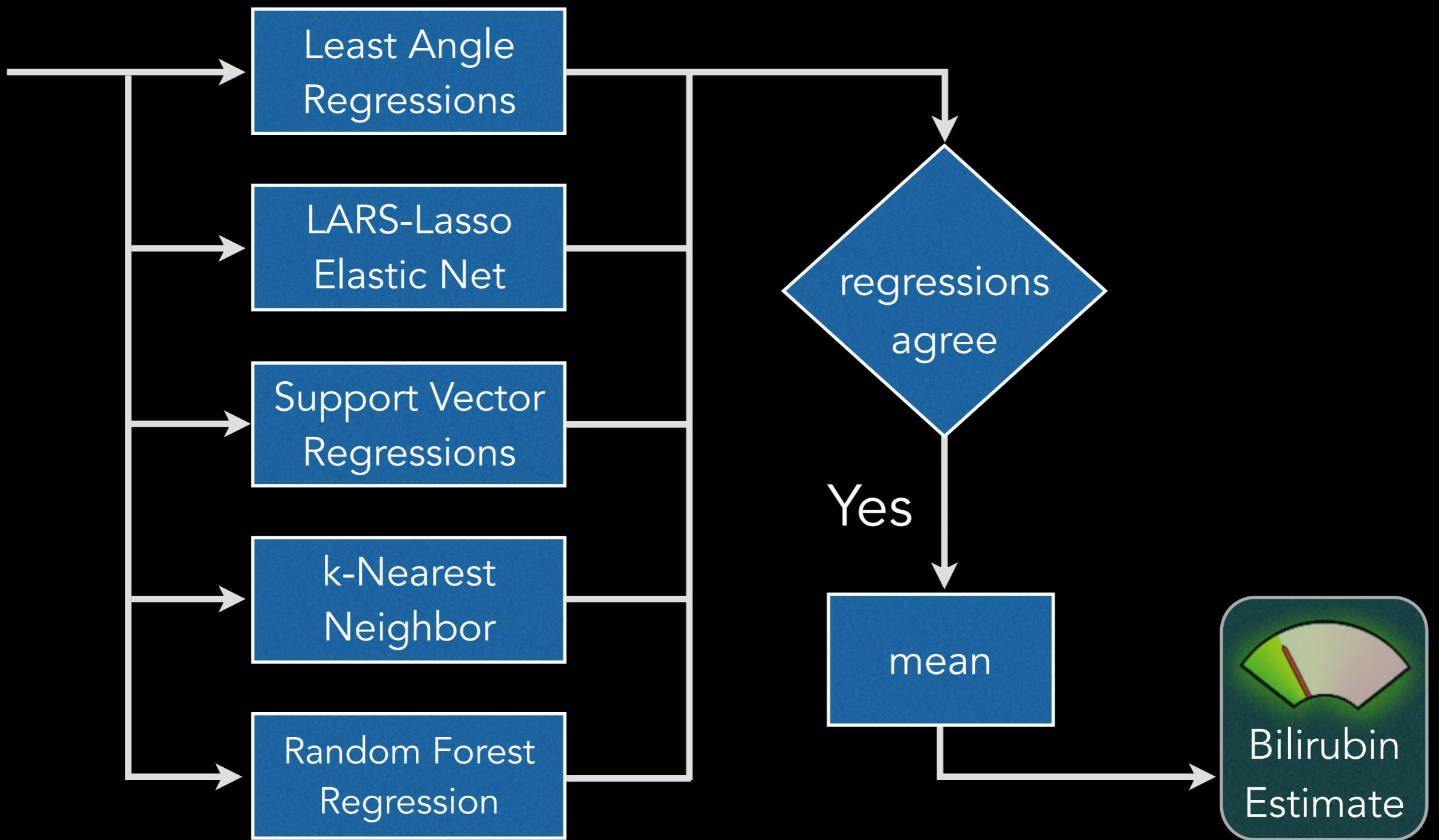
Regression Ensemble



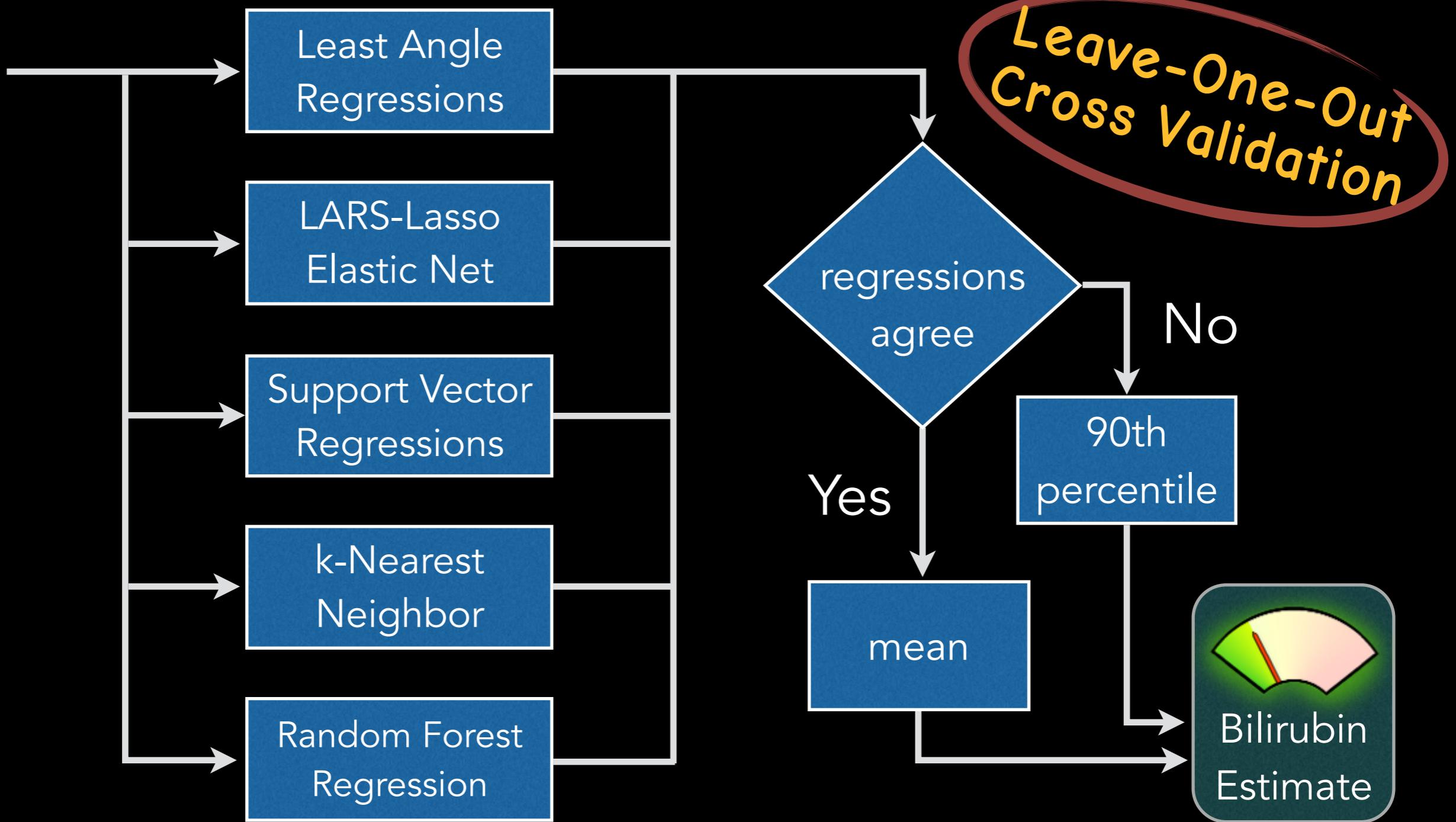
Regression Ensemble



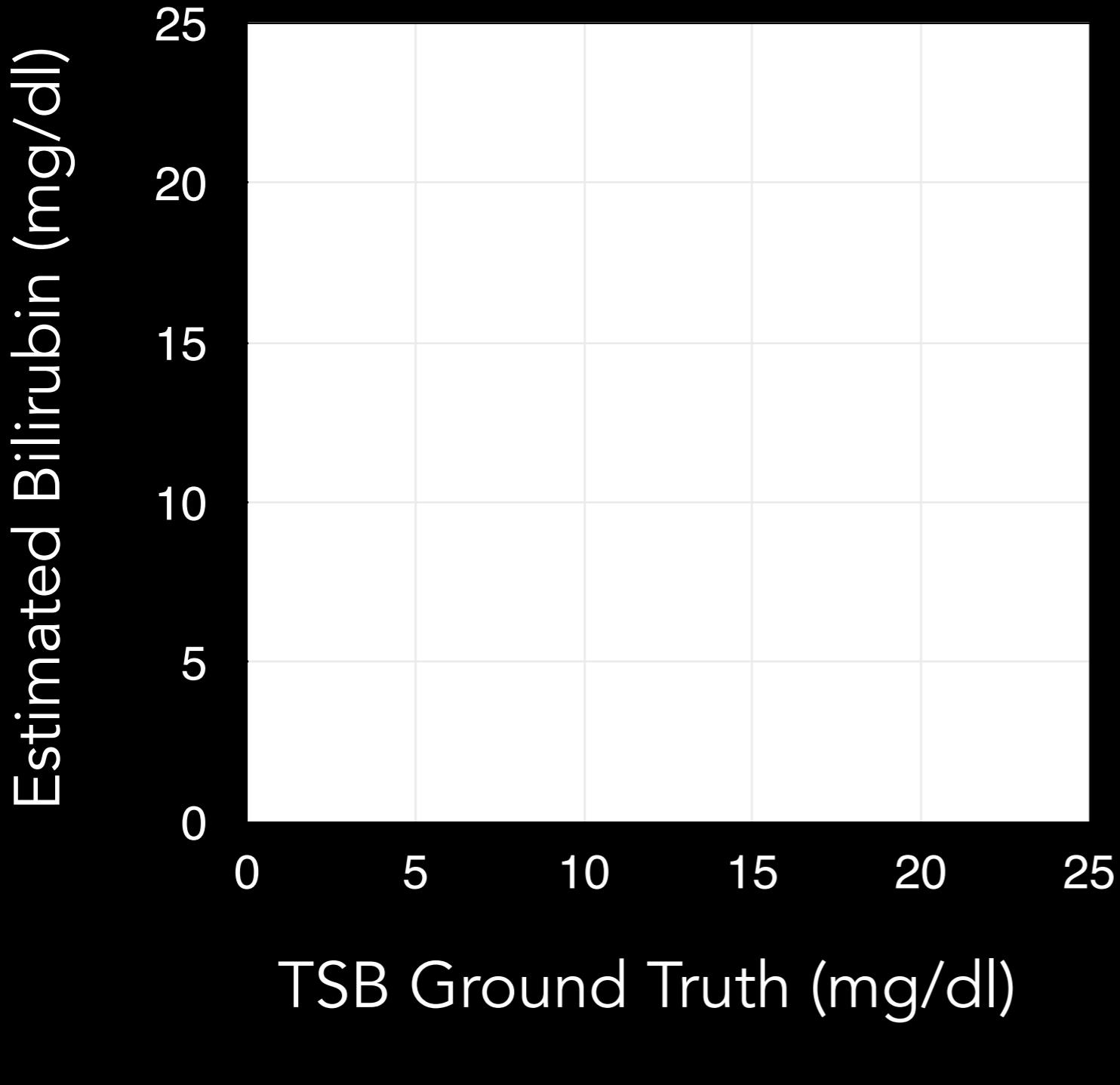
Regression Ensemble



Regression Ensemble



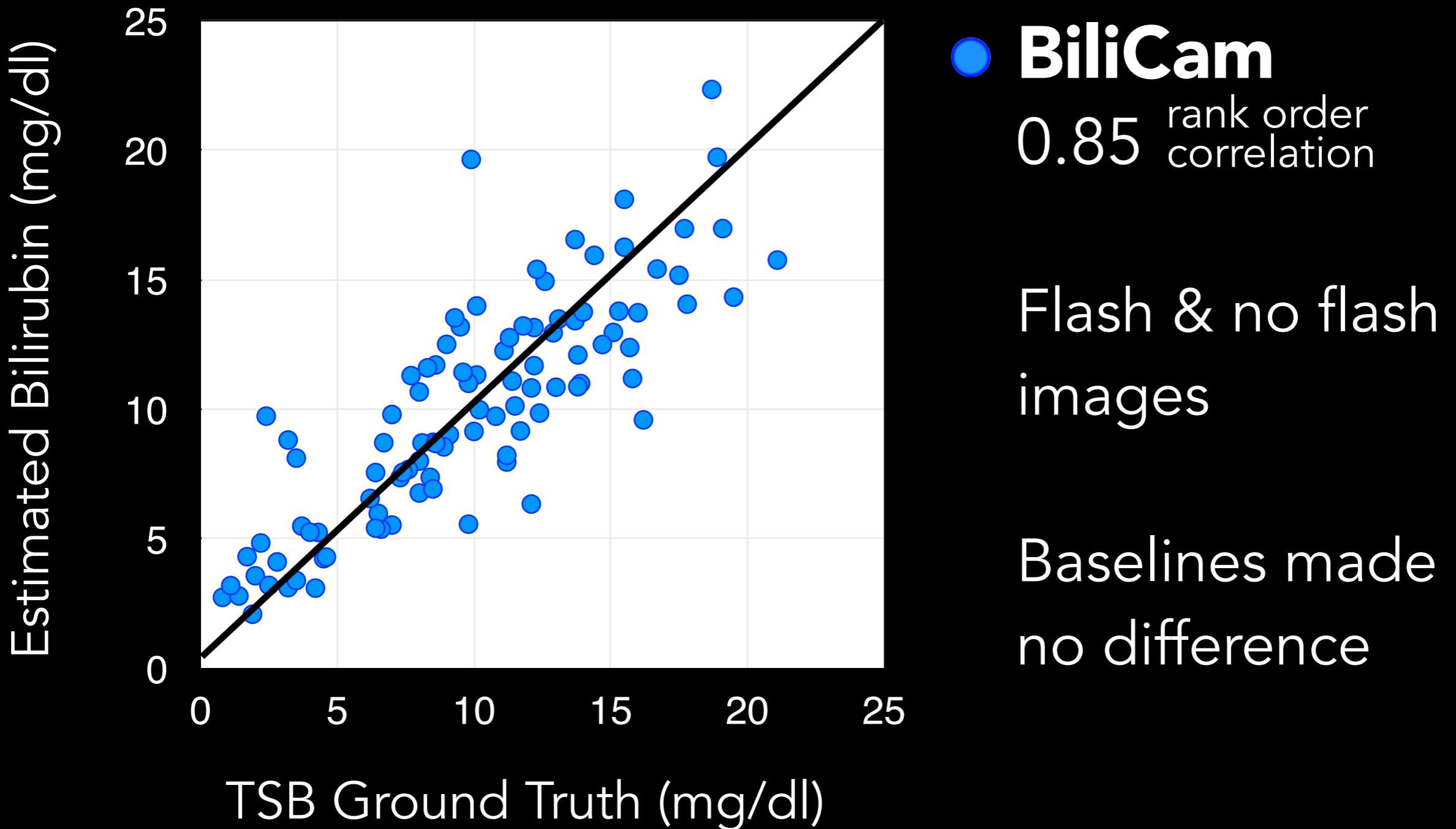
Results



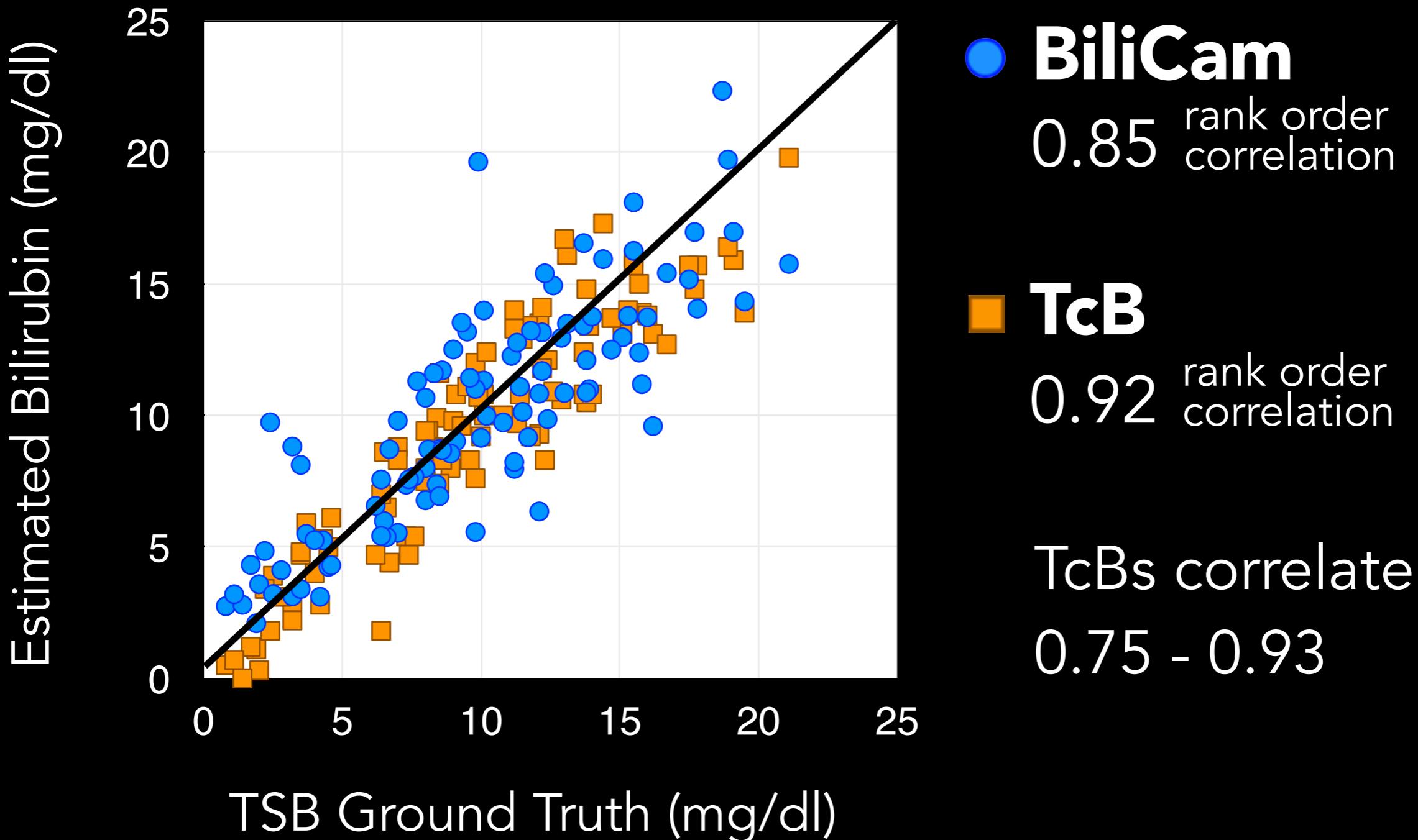
Results



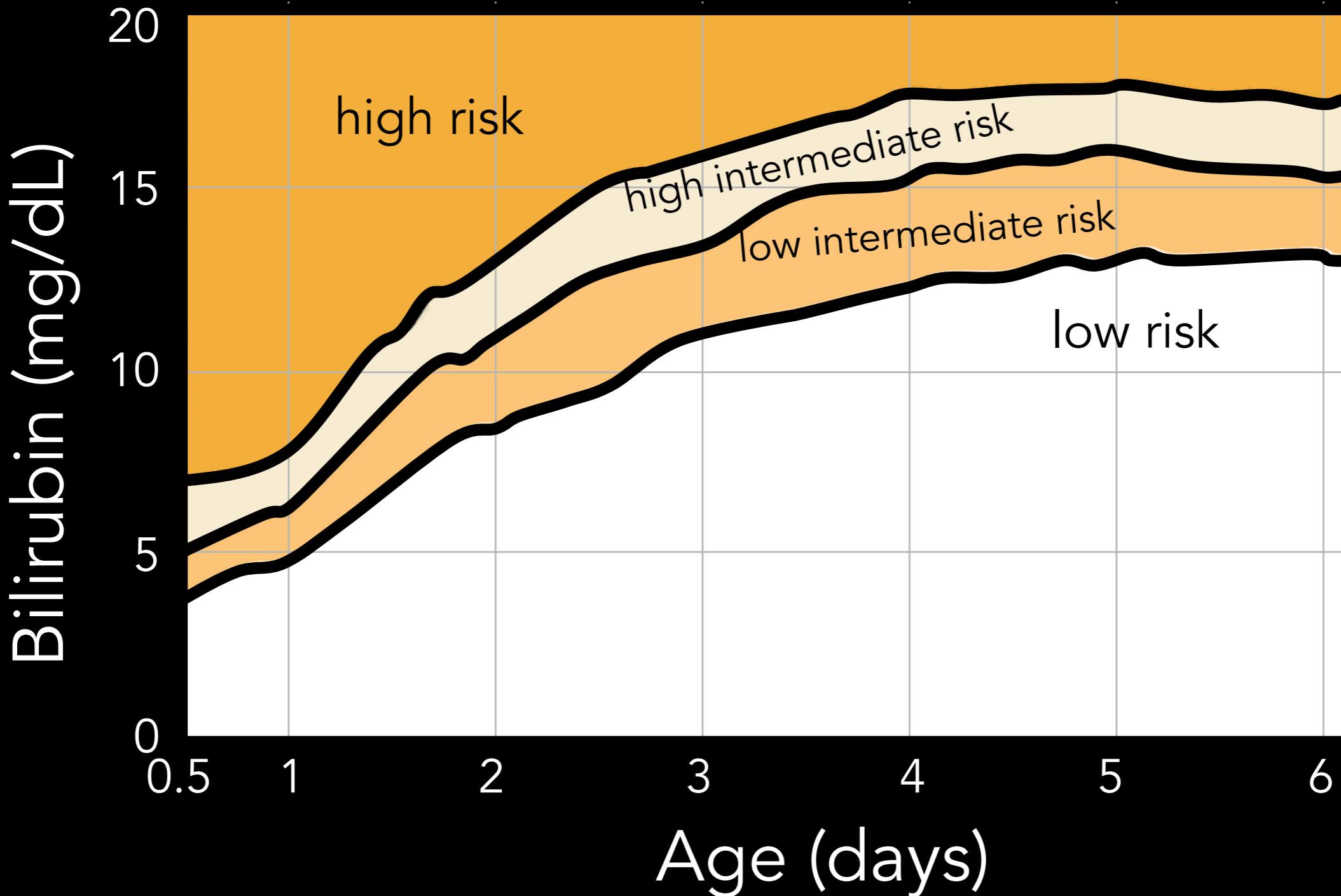
Results



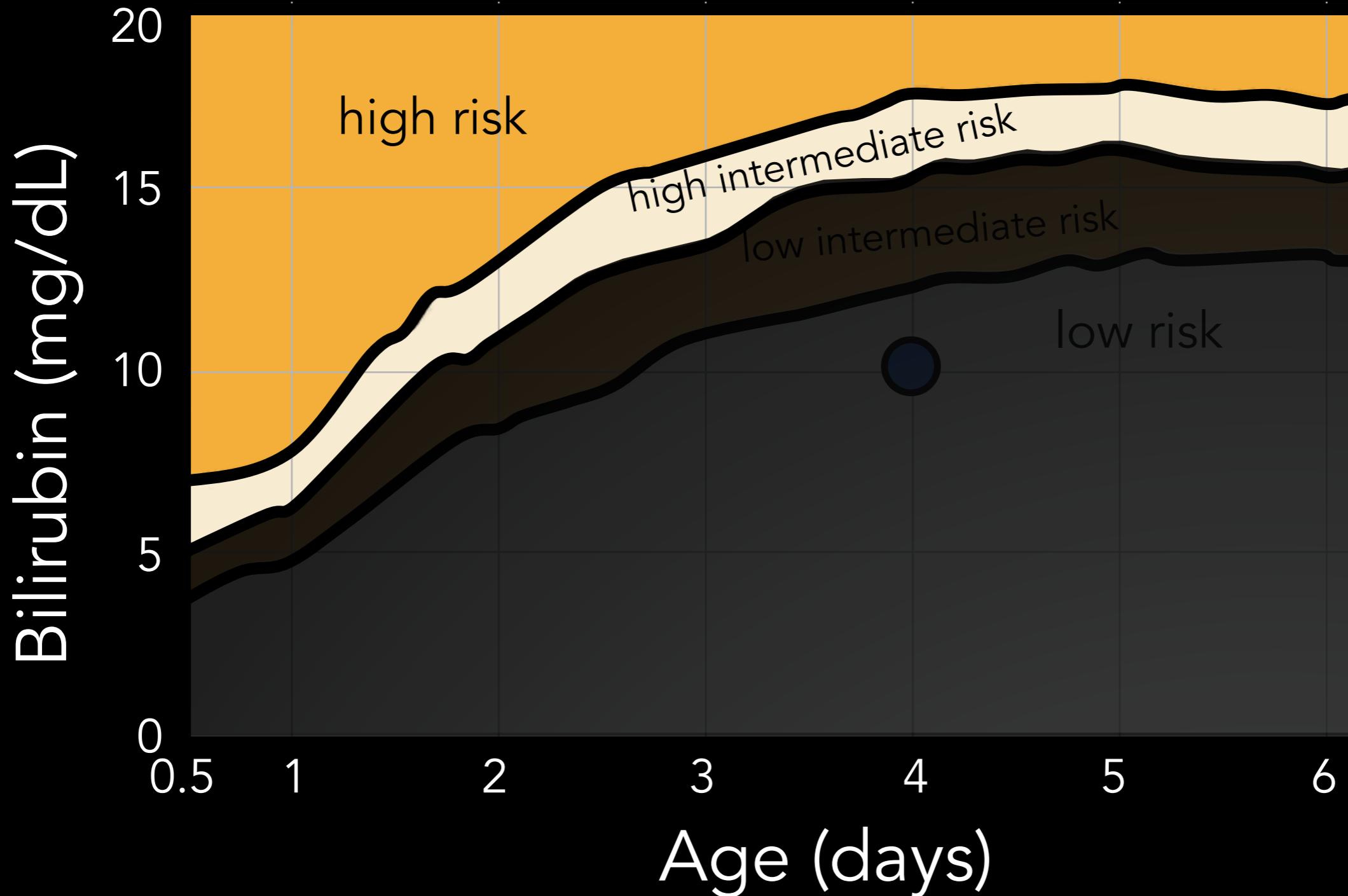
Results



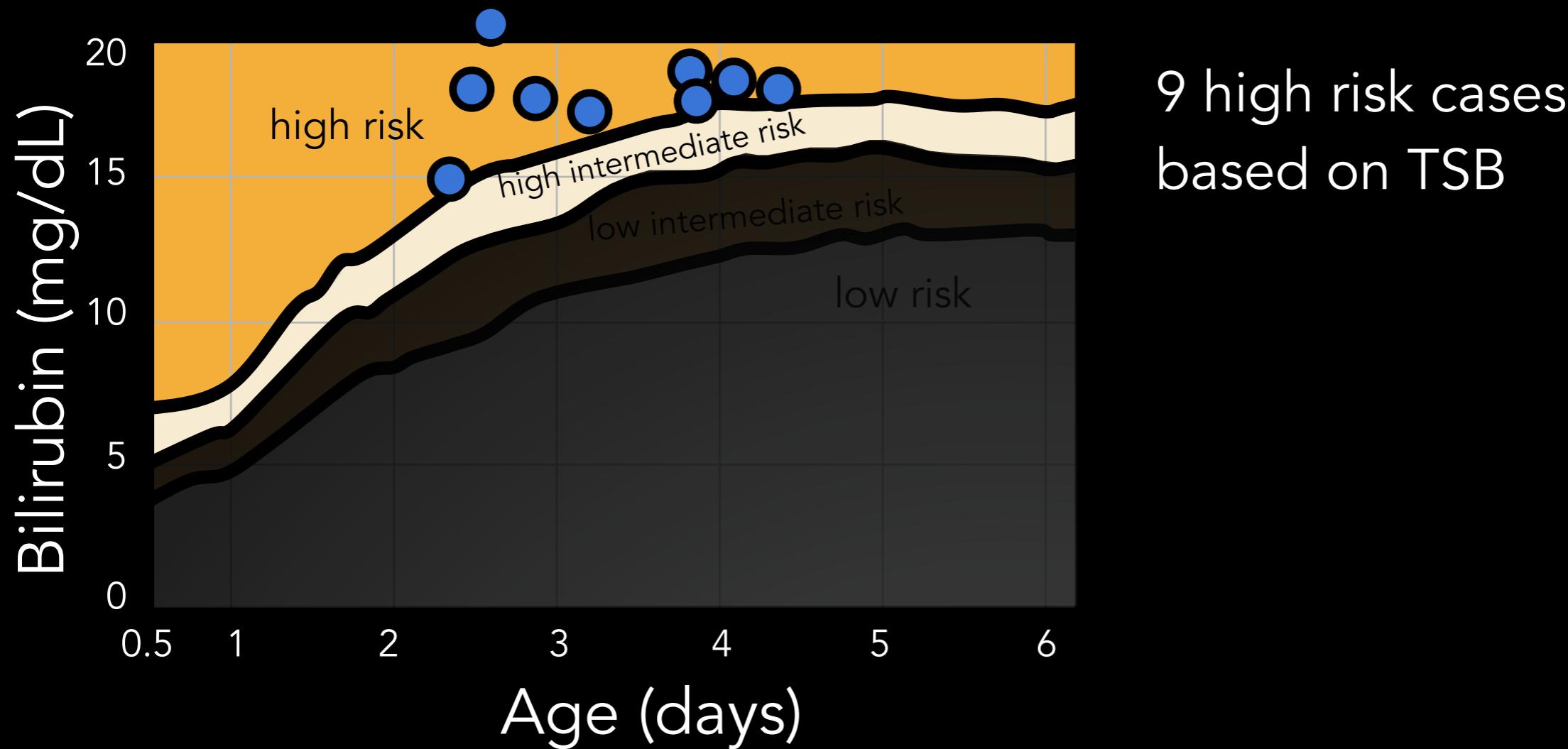
Interpretation



Bhutani Nomogram

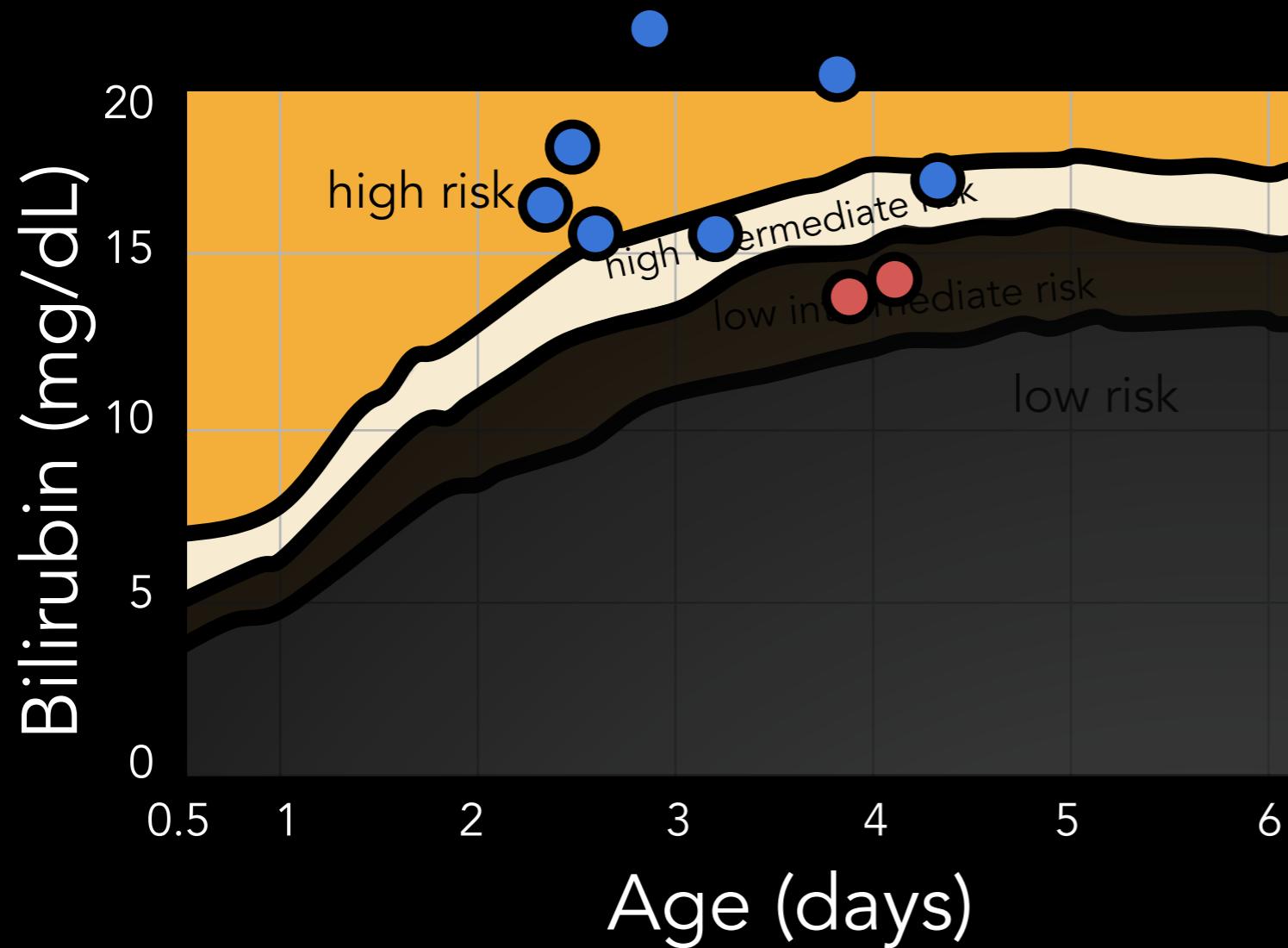


Interpretation



9 high risk cases
based on TSB

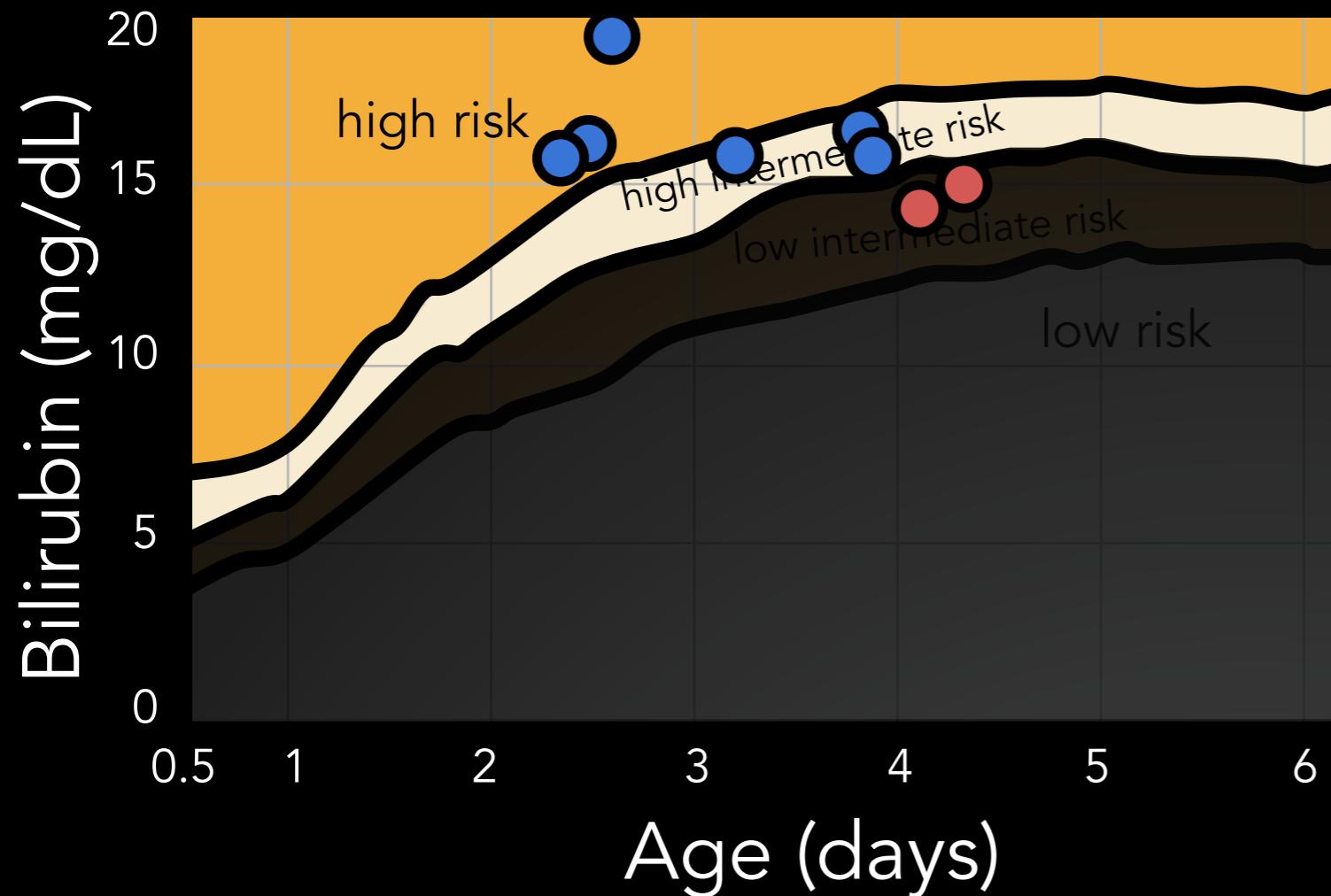
Interpretation



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

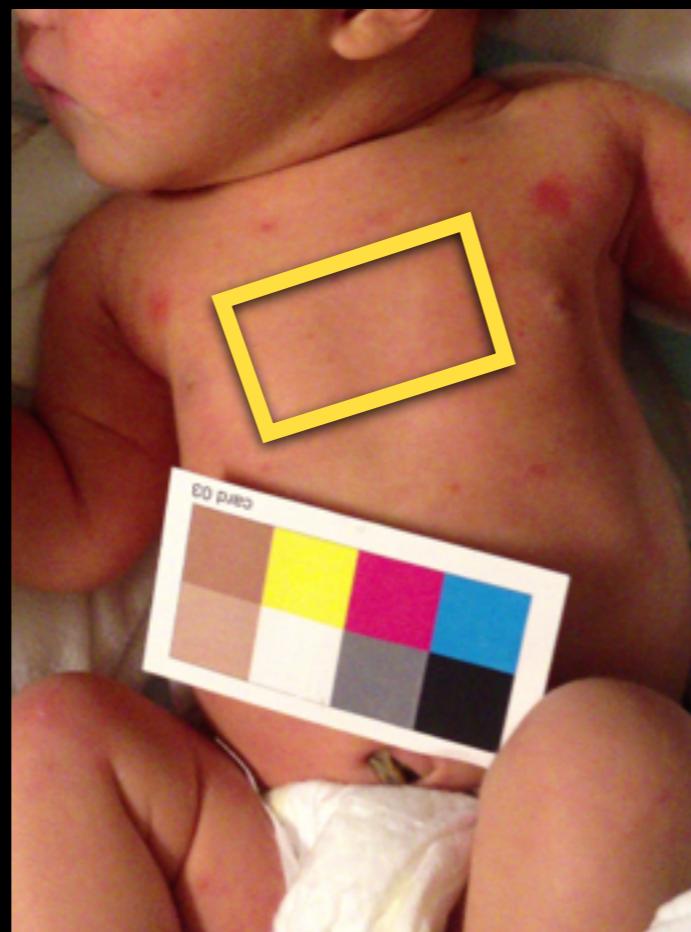
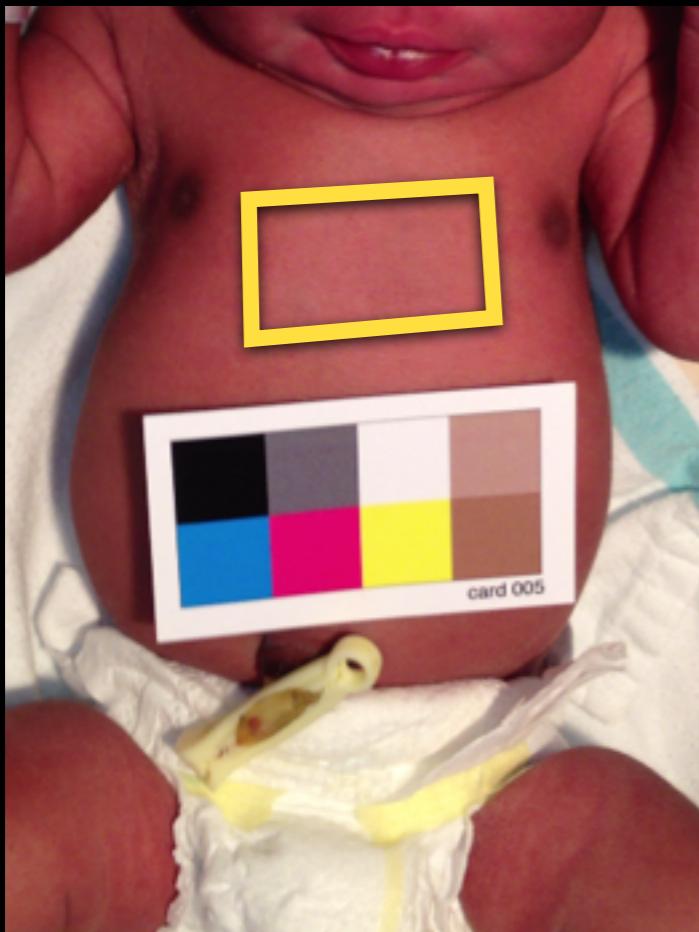


Investigate other phones

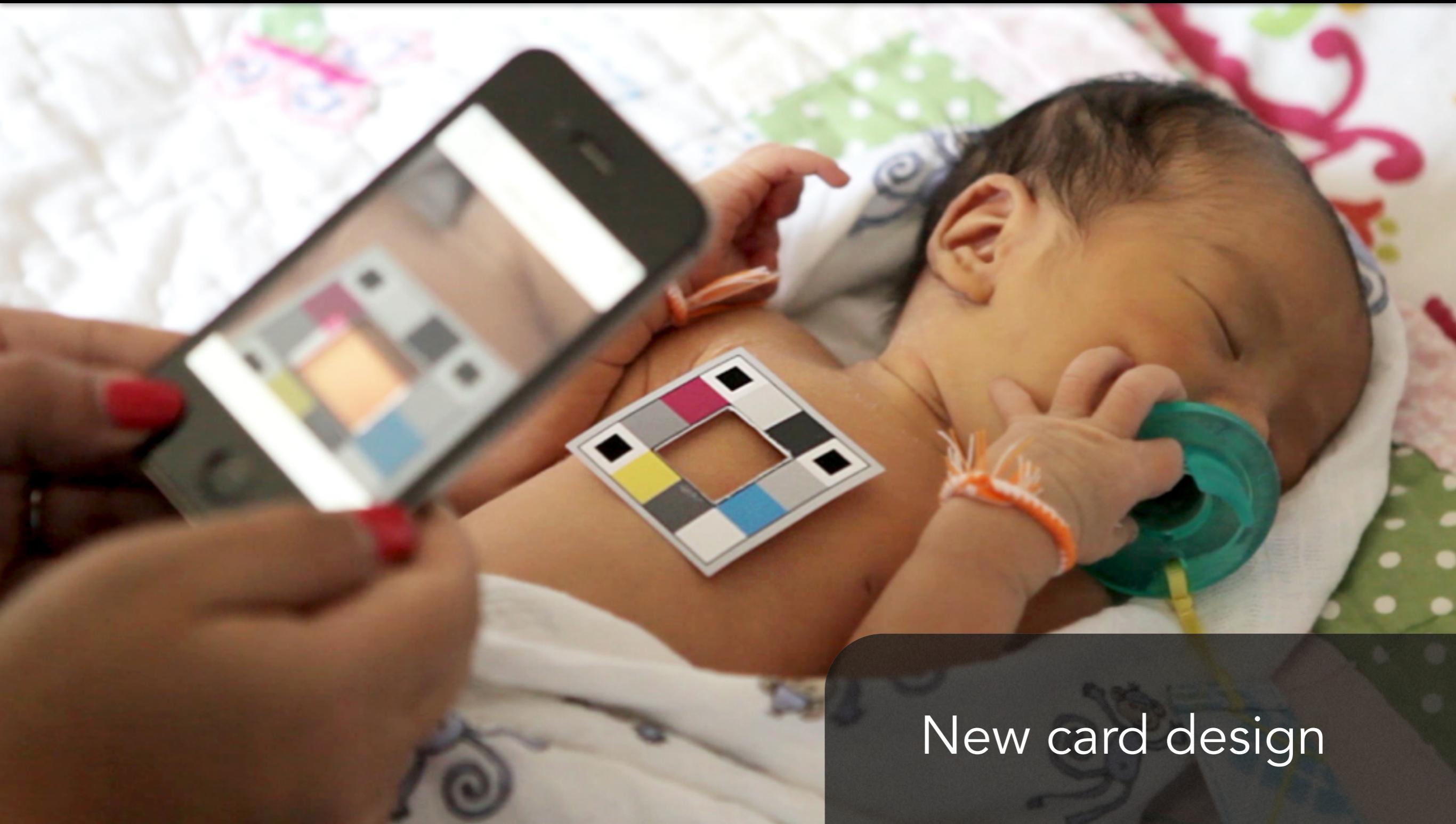


Limitations & Future Work

Good skin segmentation unclear
with current card design



Limitations & Future Work



New card design

BiliCam: Using Mobile Phones to Monitor Newborn Jaundice



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ubicomplab
UNIVERSITY OF WASHINGTON
UW Medicine

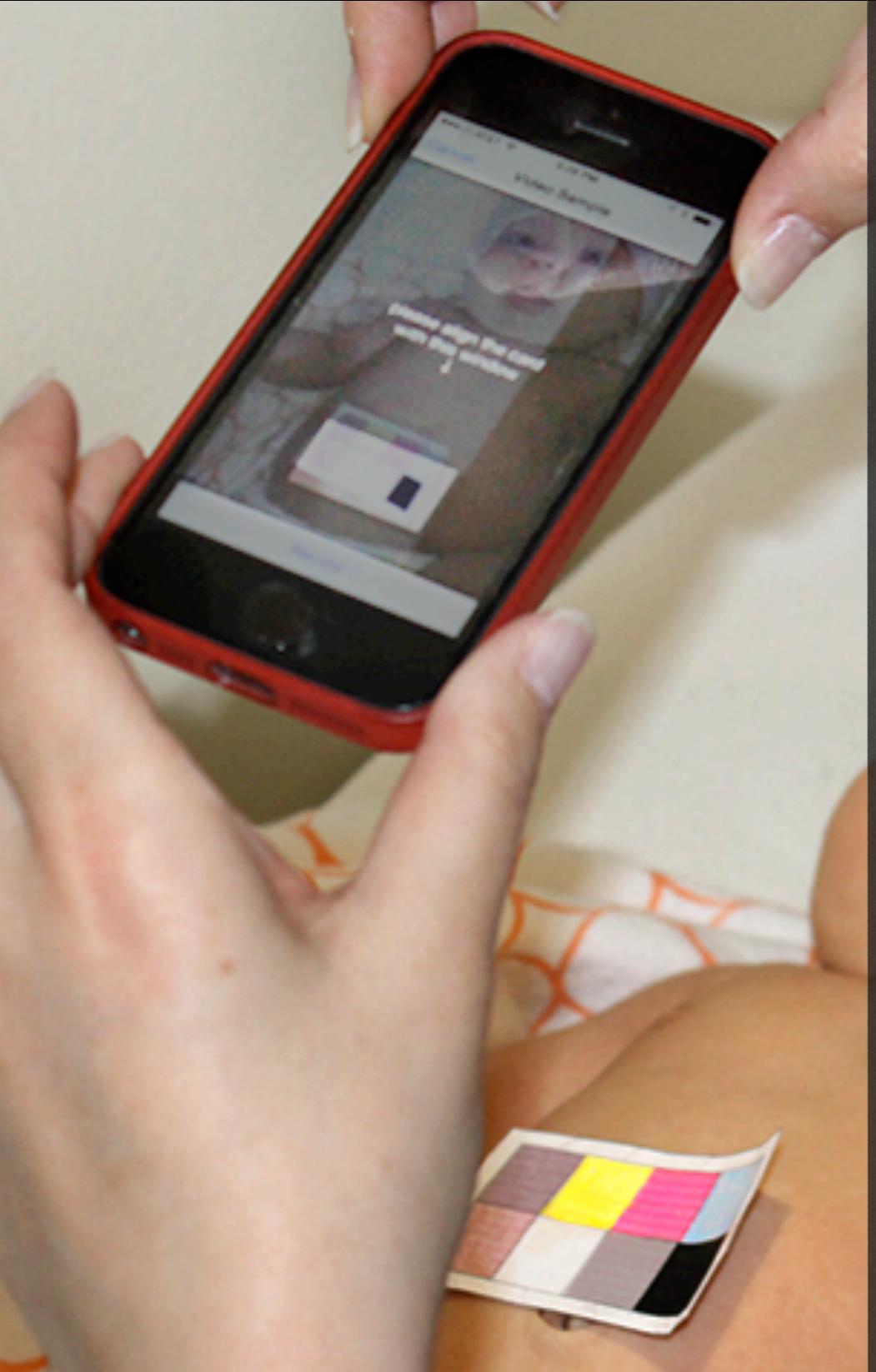


dub



BiliCam

Conclusion



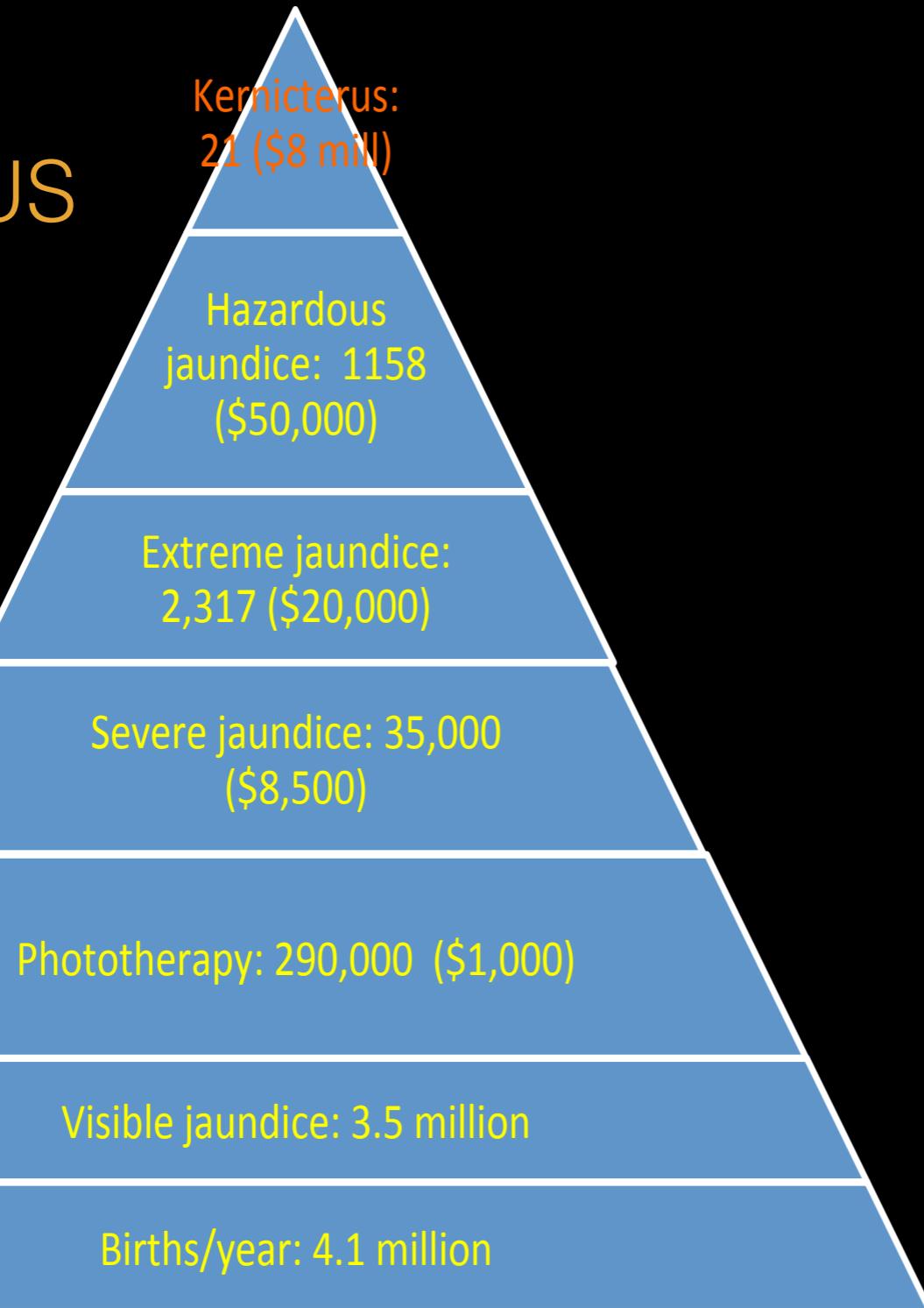
Can be effective
in-home screening tool

Estimates bilirubin
comparably to TcB

Accessible, portable, low-cost

Kernicterus Statistics

In the US



Middle- & low-income countries:

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

Study Demographics

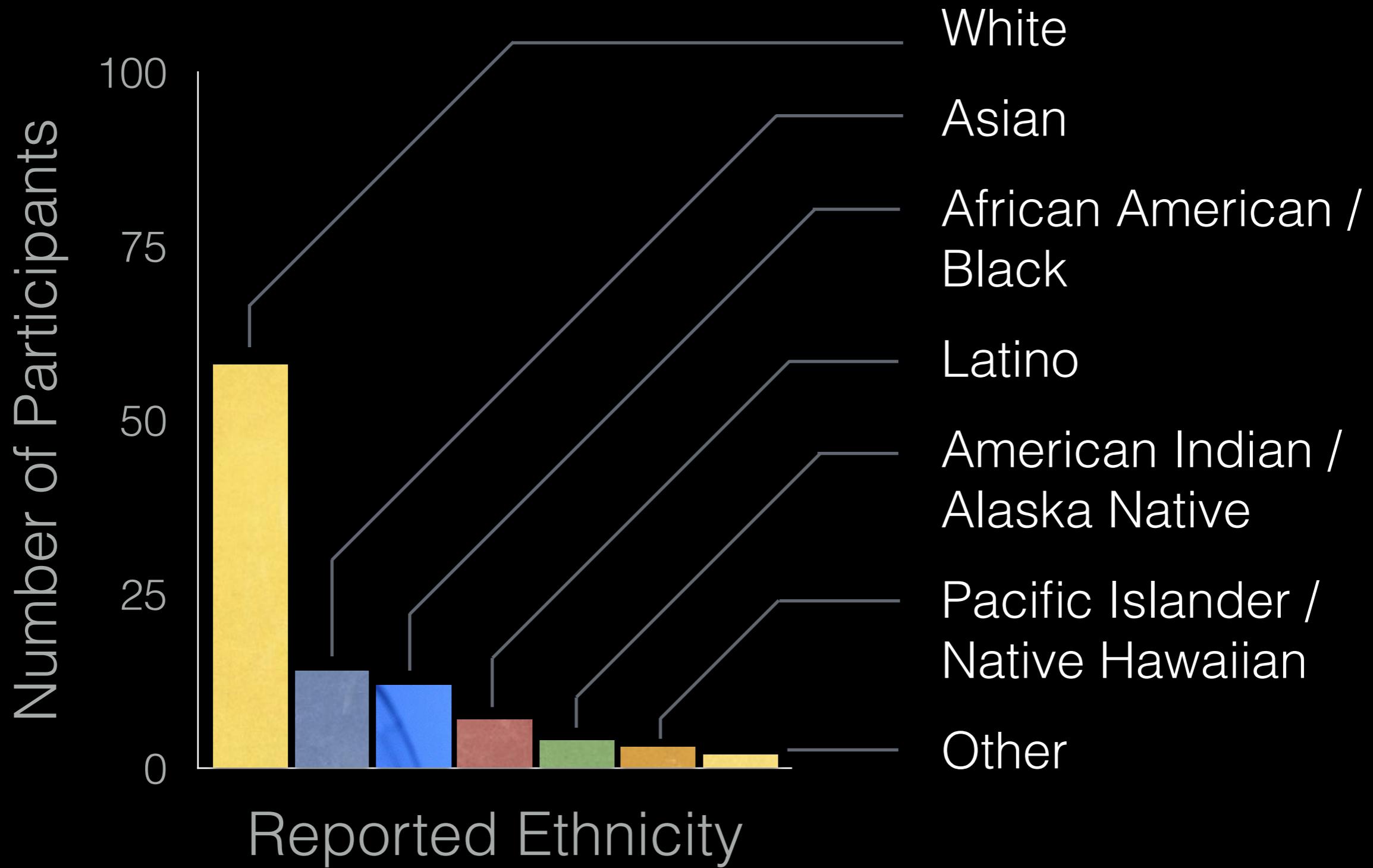
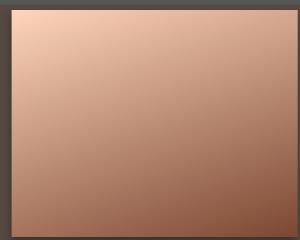
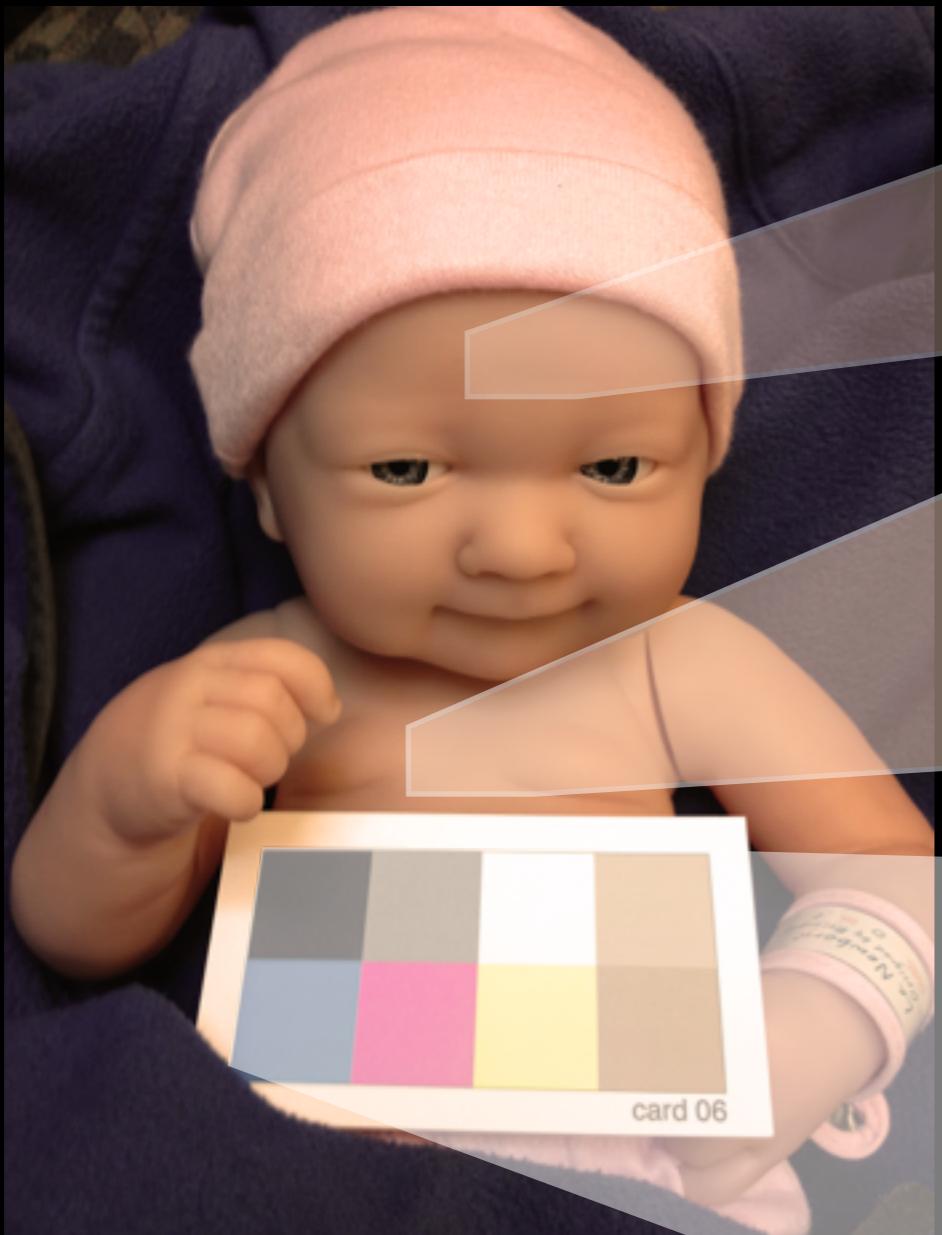
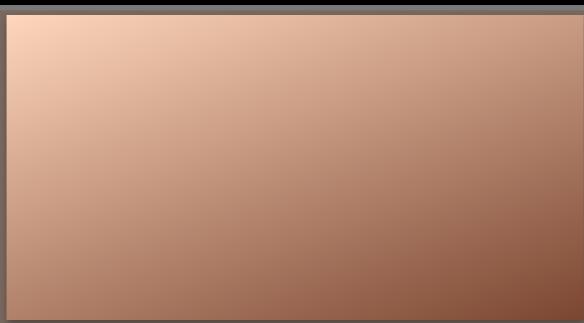


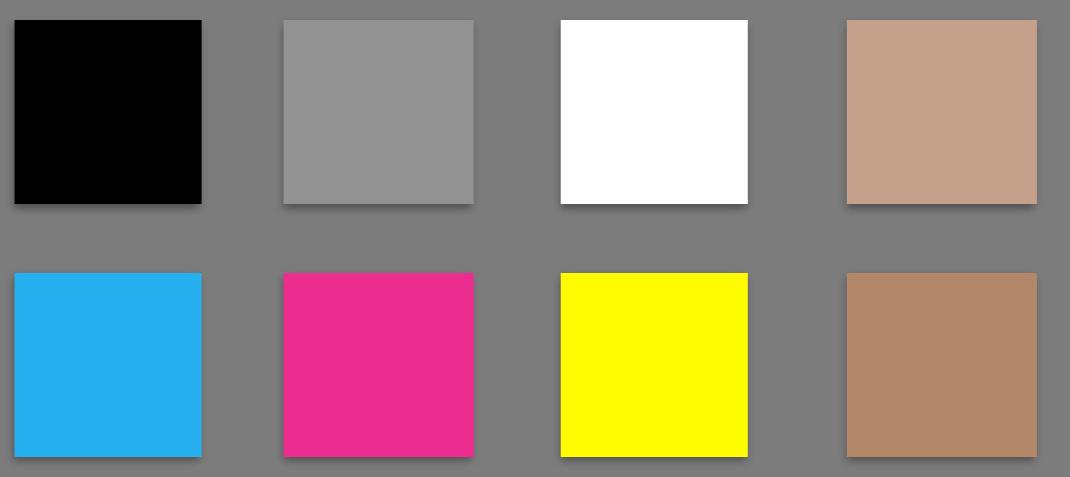
Image Segments



Forehead



Sternum



Card Patches



Icterometer