Refractive Error
Changes with Age

Emmetropization
A process that coordinates eye’s optical and axial components to result in a near emmetropic or low hyperopic refractive error

Why should I care?
Refractive error is NOT stable throughout the preschool years due to emmetropization
To adequately care for this age group must know:
What is a normal RE by age, What are normal or expected changes in RE with age
What the implications for prescribing or not prescribing for your patient

Relevant Animal Models
In a variety of animals it has been shown
That the eye changes in response to lenses, That these changes are greatest early in life
Chickens compensate over a range of -10 to +15D,Monkeys range -2D to +8D
Human compensation range is not yet known, Based on BIBS may be +1 to about +5

Implications of Emmetropization
Prescribing lenses to young children may impact or alter natural emmetropization process
Not prescribing could result in:
Amblyopia, Strabismus, Reduced BV function
Plano lens in Monkey
Emmetropization in Humans
The average amount of RE decreases after birth
The width of the distribution of RE’s narrows after birth
Exact mechanisms responsible for emmetropization are not known
Process appears to visually guided
Bi-directional with decreases occurring in both myopic and hyperopic infants

Visually Guided Mechanism
Eye detects and responds to the RE
Rate of RE change and axial growth is proportion to ametropia present at birth
Higher initial levels of hyperopia related to faster rates of axial growth
If near emmetropia – little change in RE
If large ametropia (Mutti’s study over 5D) also little change in refractive error

Visually Guided Mechanism
Without visual feedback (form deprivation)
Eye becomes very myopic
Emmetropization appears to depend on retinal image to regulate eye growth
Exact mechanism not known
Blur/defocus
Accommodative effort
Peripheral Refraction and Central Refraction may both play a role
Current Understanding
Most infants born hyperopic
Hyperopic defocus caused by hyperopic RE, modulates eye growth to reduce RE thru axial elongation

Spherical Refractions at Birth
May vary with ethnicity
Cook and Glasscok (1951) – following 1% atropine gel (63% African Am, 10 preterm in sample of 1000
73% where hyperopic (0.25 to +12.00)
50% were less than +3.00D
23.1% myopic (0.25 to -12.00D)
83% under -5.00
0.8% emmetropic

Spherical Refractions at Birth
Zonis and Miller infants 5.5lbs or more
73.8% hyperopic
14.5% myopic
11.7% emmetropic
Mayer healthy full-term, RE by cycloplegic refraction at 1 month in 85% white sample
Mean SE RE +2.20D (±1.6D)
1 of 514 was myopic (0.19%)

Longitudinal Study - Bibs
Cycloplegic refraction of 222 infants; (74.2% white; 11.8% Asian American)
3 mo, 9, mo, 18 mo
SE RE at 3 months =+2.16 ± 1.3D
SE RE at 9 months = 1.36 ± 1.06
SE RE at 18 months = 1.10 ± 0.90
Time Course of Emmetropization
Stable over the first 3 months
Majority of change between 3 and 9 months
Most complete by the end of first year

Mutti et al IOVS 2005

Mayer et al 2001 Arch Ophthal
Mayer et al 2001 Arch Ophthal

Changes over childhood
Emmetropization
Individuals relative position within the RE distribution typically does not change even though shape and mean of distribution does change
Initial large hyperopic RE, will tend to be more hyperopic than average once stabilized following emmetropization (Smith & Hung 1999)

Spherical Refraction Summary
Most full term infants are hyperopic
Average RE is about +2.00 with SD around 2
By end of 1 year average about 1.00 to 1.25 D with SD of about 1 D

Consensus at 9 months
9 months - cross-sectional data from Mayer
1.32 ±1.13
95% upper limit is 3.63 D to -0.99 D
9 months Mutti – longitudinal data set
1.36 ± 1.06

Consensus at 18 months
18 months - cross-sectional data from Mayer
1.23 ±0.91
95% upper limit is 3.09D to -0.64 D
18 months Mutti - longitudinal data set
1.10 ± 0.90
Beyond 18 months
2 years
  1.19 (0.83)
  95% limits 3.16 and -0.01
3 years
  1.00 (0.76)
  95% limits 2.56 to -0.56
4 years
  1.13 (0.85)
  95% limits 2.89 to -0.62

What Produces Change in RE
Biggest change is from increases in axial length
Thinning of crystalline lens
Flattening of crystalline lens
Decrease in lens power
Decrease in corneal power

What Spherical RE is Abnormal?
Mutti data 2 x SD
  3 months would be +5.00
  9 months would be +3.50
  18 months would be +3.00
  Myopia very rare in full term infants

NLDO data
At average age of 15mo with 90% 2 yrs or less
95% had RE less than +3.25 D
Only 2 OD (1.54%) had myopia of ≤ -1.00D

What Spherical RE is Abnormal?
Myopia and anisometropia are rare
  Mayers cross-sectional sample from 1-48 mos
    3% myopic
    1% anisometropic
  After 1 year, myopia in full term healthy infant is very rare

Astigmatism varies with Ethnicity
Native Americans in AZ 1 – 8th grade (OVS 2006)
  Noncycloplegic screening
    > 1.00 D in right or left eye = 42%
  • Almost all with the rule
CLEERE study 1 – 8th grade (Arch Ophthal 2003)
African American > 1.00 = 20%
White = 26%
Asian = 34%
Hispanic = 37%
Astigmatism
Other Cross-sectional Data
Mayer 1 to 48 months
- 25% had astigmatism
- Only 3% were ≥ 2.00D
- More prevalent under the age of 9 months
  - Against the rule (56%); with the rule 28%, oblique 14%
Cook & Glasscock
- 38.4% with astigmatism
Astigmatism
At birth
   Percentage with astigmatism is
      5 times that found in adults
      10 times that reported for older children

Astigmatism common before age 2 years
Amount of astigmatism and number of children with astigmatism reduced by age 18 months to 3 years
Infant astigmatism is primarily corneal
Higher the power the greater the correlation with corneal astigmatism

Limits of anisometropic compensation appear to be about 3D (Abrahamsson & Sjostrand, 1996)

Preterm Infants Without ROP
Compared to full term infants
   Shorter axial length
   Shallower anterior chambers
   More highly curved corneas
Most are myopic at 32 weeks
Become emmetropic around term
Less hypermetropic towards end of study
Cook, White, Batterbury and Clark IOVS 2008 49:5199

Pretrem without anomalies
Gestational age at birth less than 36 wks
All refracted before 8 wks w cyclopentolate
No ROP or ocular abnormalities
  OD -0.69 (2.8)
  OS -0.41 (2.8)
Birth weight and amount of myopia not correlated
Gestational age & amount of myopia may be correlated

Preterm Infants
Higher rates and amounts of myopia, particularly if treated for ROP
Higher rates of astigmatism
Higher rates of anisometropia

Preterm Infants with ROP
If treated for ROP
  RE changes very little
  Less hyperopia at 1 year compared to untreated preterm eyes