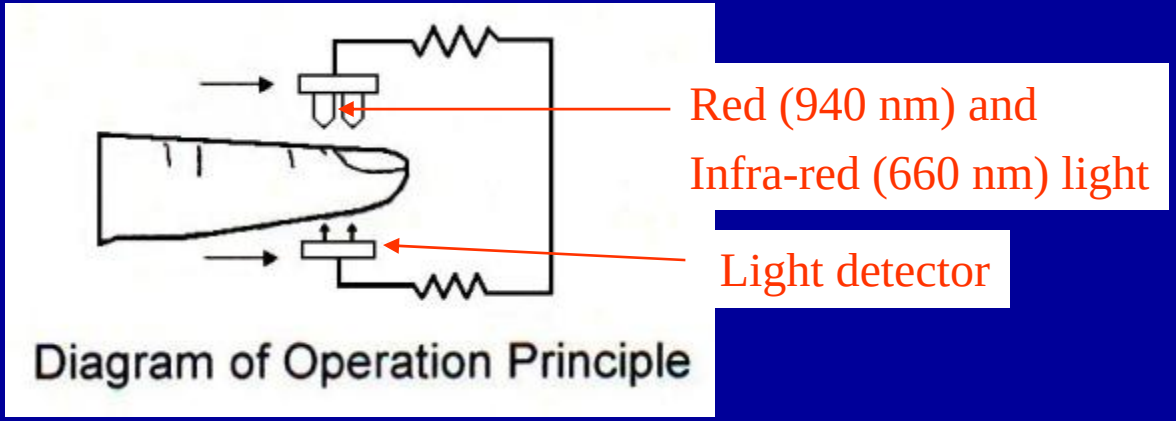
Pulse oximetry

How does it work?



- A light emitter and detector
- Oxygenated haemoglobin absorbs mainly infra-red light (660nm)
- De-oxygenated haemoglobin absorbs mainly red light (940nm)
- Ratio of absorbed red to infrared light indicates degree of oxygenation of blood

How does it work?

Light at two wavelengths passes through a blood vessel

Reflected light	Preferential wavelength
1. Deoxygenated Haemoglobin	940 nm
2. Oxygenated haemoglobin (HbO_2)	660 nm

$SpO_2 = [HbO_2 / (HbO_2 + \text{Deoxy-Hb}) \times 100]$

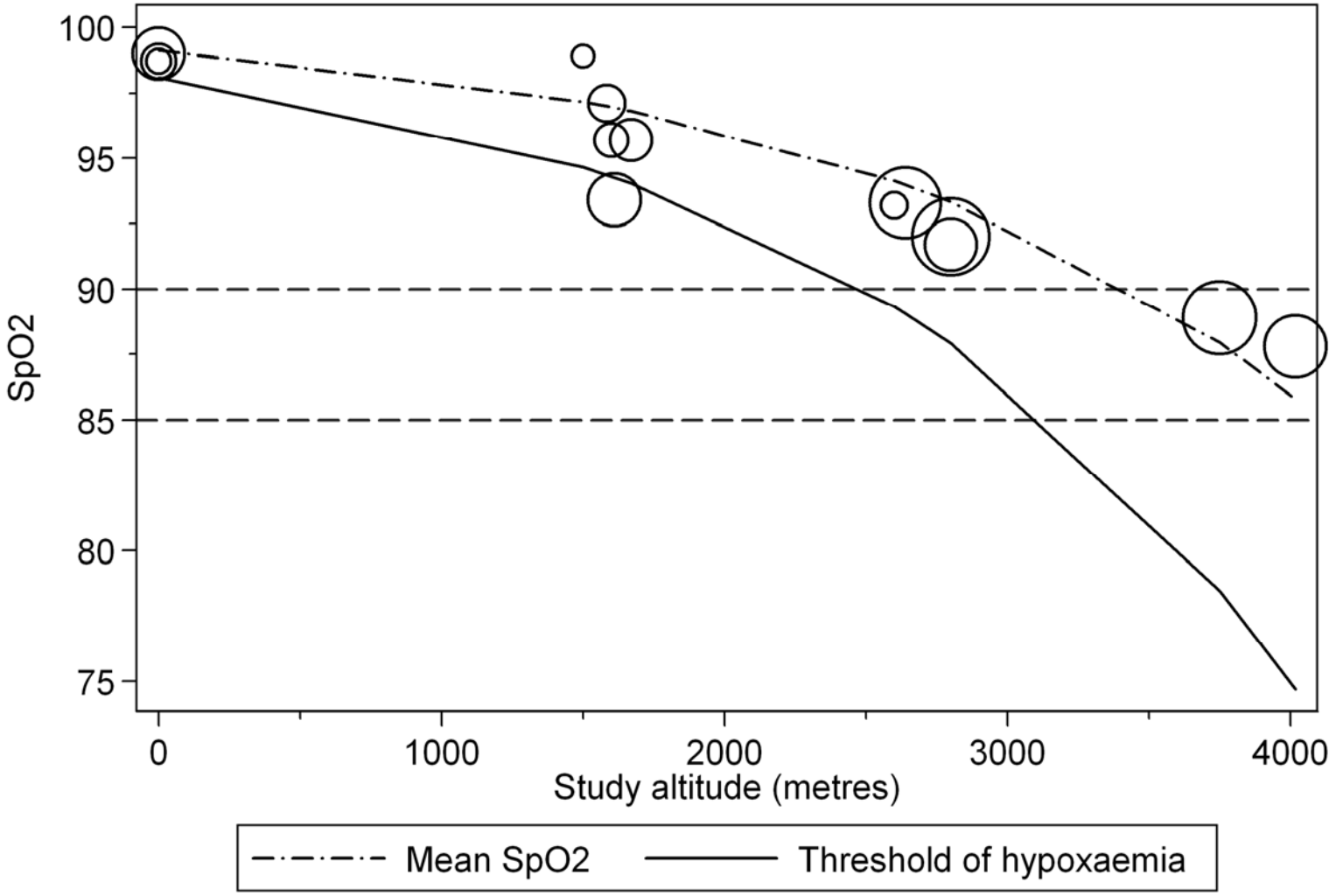
Normal oxygen saturation

- SpO_2 is arterial oxygen saturation measured by pulse oximetry
- Normal SpO_2 is lower at higher altitudes due to the lower partial pressure of inspired oxygen (PiO_2)

Definition of hypoxaemia

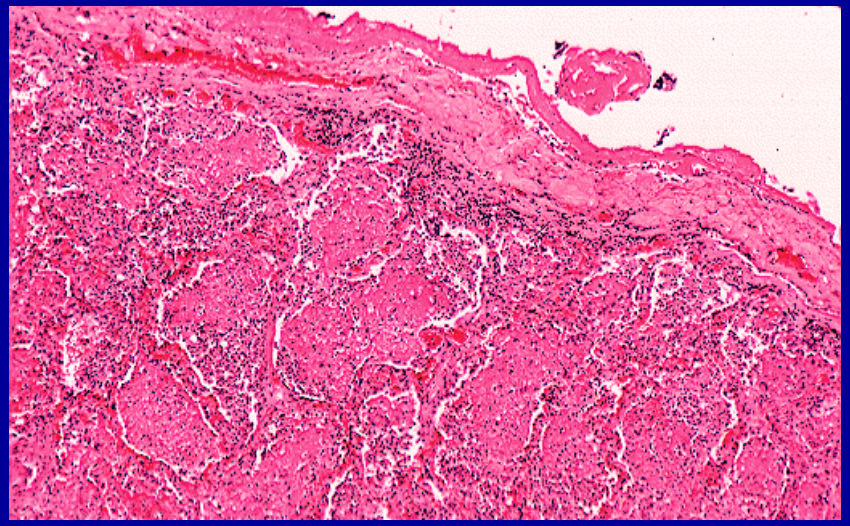
- Ideally defined as any level of SpO_2 low enough to result in adverse outcomes
- Practically, often estimated as any SpO_2 below the statistical lower limit of the normal range for a population
- SpO_2 defining hypoxaemia lower at high altitude due to lower PiO_2

Arch Dis Child 1997; 76:310-314



Hypoxaemia in pneumonia

1. Decreased FiO_2 ($P_{atm}O_2$)
2. Decreased V_m
   - Poor lung compliance
   - Airway secretions
3. V/Q miss-matching
   - Alveolar consolidation
     - inflammatory cells
     - oedema fluid
4. Right to left shunting
   - Alveolar consolidation
   - Loss of hypoxic-pulmonary vasoconstriction
5. Diffusion abnormality
   - Chronic alveolar changes



Prevalence of hypoxaemia in pneumonia

- 13.3% of children with hospitalized pneumonia (WHO classification) are hypoxaemic
- This corresponds to 1.5-2.7 million annual admissions with hypoxaemic pneumonia

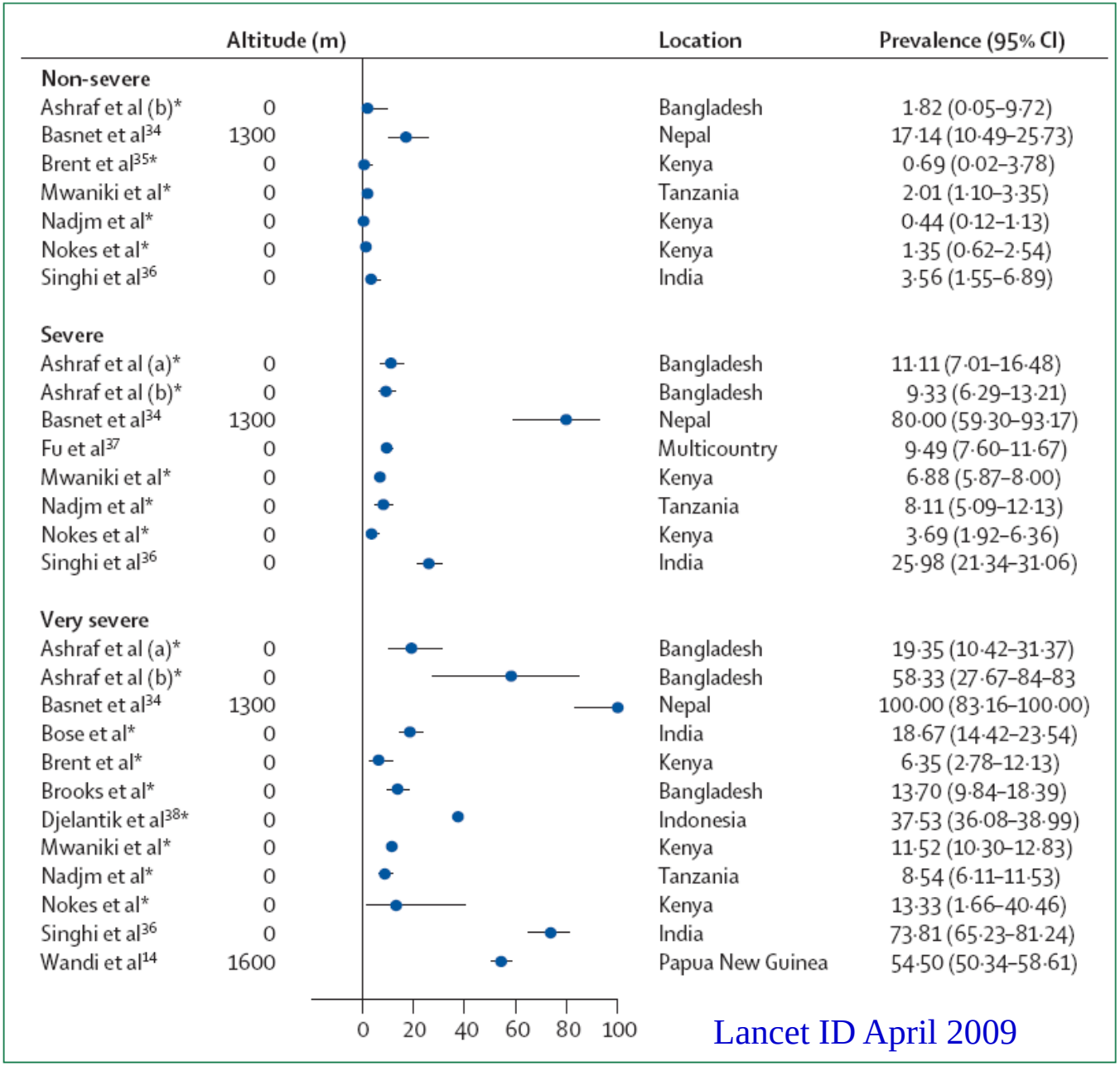


Figure 2: Hypoxaemia prevalence in WHO non-severe, severe, and very severe pneumonia

Prevalence of hypoxaemia in other conditions

	Patient age	Patients with diagnosis (total sample size)	Prevalence of hypoxaemia (%)
Malaria			
Junge et al[40]	0–10 years	1044 (3269)	30 (2·9)
Maitland et al[58]	0–5years	501 (501)	86 (17·1)
Mwaniki et al	0–5 years	4982 (15 297)	244 (4·9)
Wandi et al[14]	0–unspecified (median age 11 months)	272 (1313)	9 (3·3)
Meningitis			
Junge et al[40]	0–10 years	74 (3269)	2 (2·7)
Nadjm et al	2 months to 13 years	21 (3683)	2 (9·5)
Wandi et al[14]	0–unspecified (median age 11 months)	41 (1313)	6 (14·6)
Neonatal illnesses			
English et al[59]	Younger than 30 days	376 (1080)	87 (23·1)
Junge et al[40]	Younger than 1 month	259 (3269)	51 (19·7)
Mwaniki et al.	Younger than 7 days	1105 (15297)	206 (18·6)
Weber et al[33]*	Younger than 1 month	724 (4552)†	129 (17·8)

Lancet ID April 2009

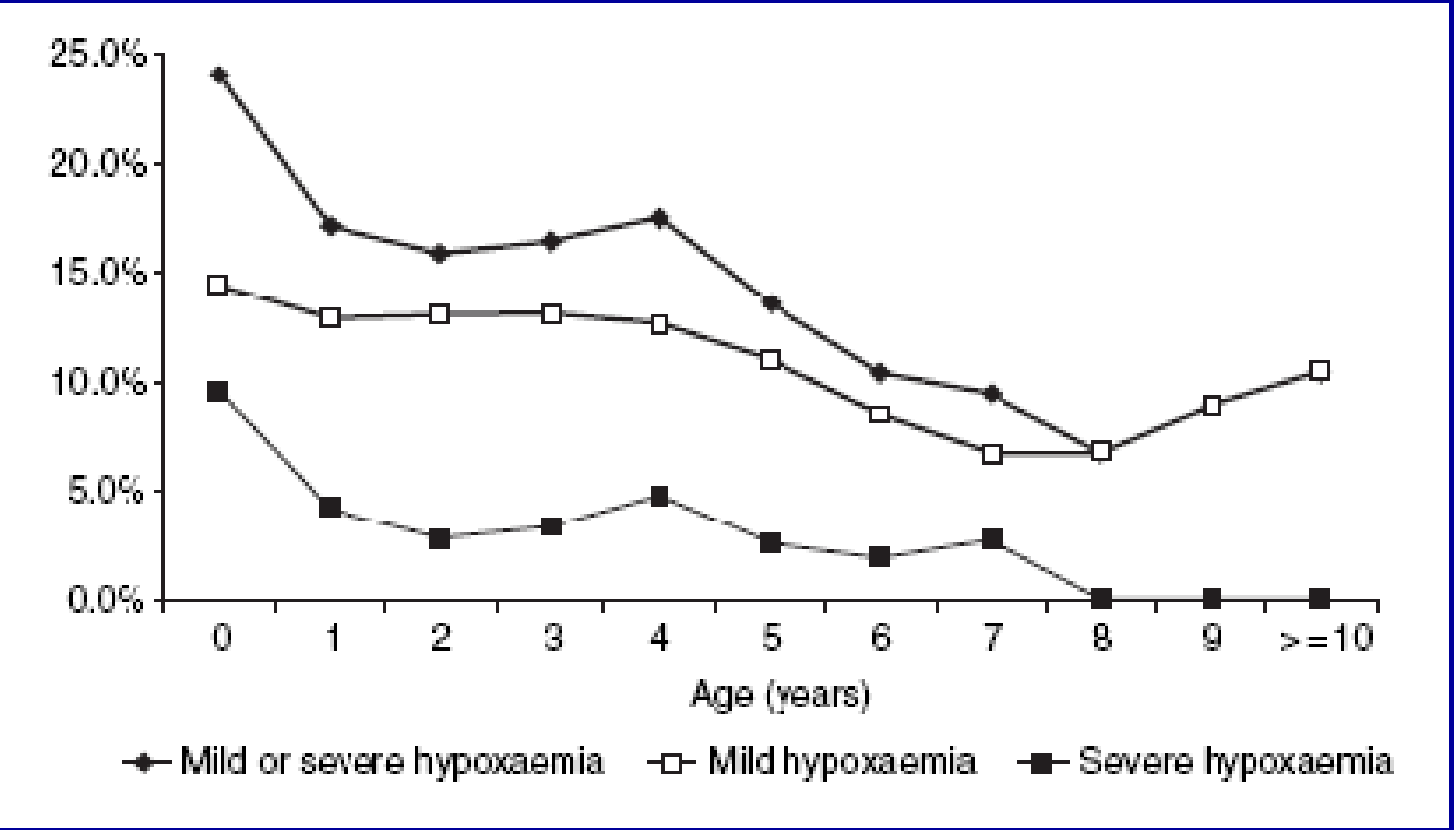
Hypoxaemia in meningitis

Arch Dis Child 2002;86:108-111

- In a study of childhood meningitis, 21 of 40 (53%) had SpO_2<88%:
- Causes of hypoxaemia included:
  - Co-existent pneumonia
  - Impaired respiratory drive
  - Retained respiratory secretions
  - Upper airway obstruction
  - Aspiration
  - Convulsions

Prevalence of hypoxaemia by age

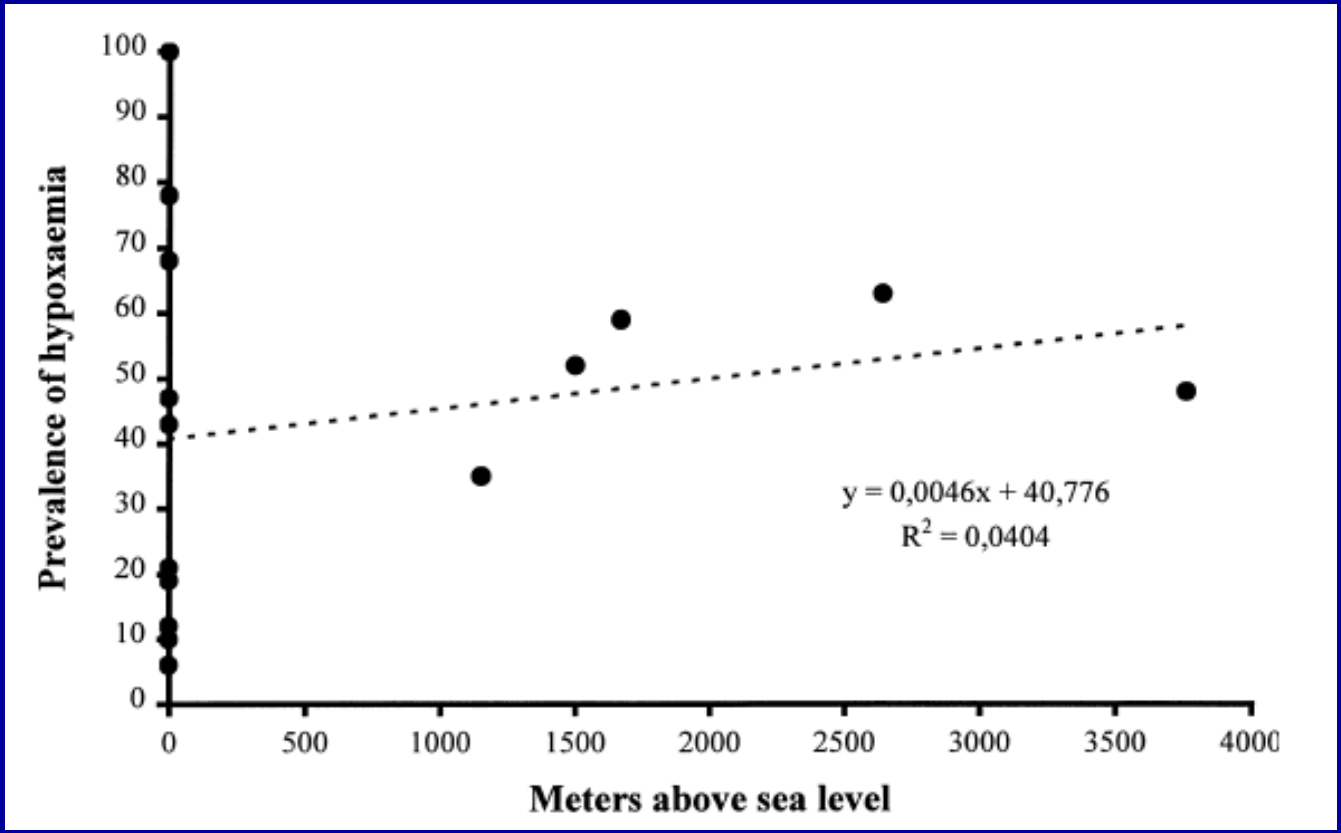
Hypoxaemia is more common in younger ages



Trop Med Int Health 2006; 11(3):367-72

Prevalence of hypoxaemia by altitude

Hypoxaemia is more common at higher altitudes



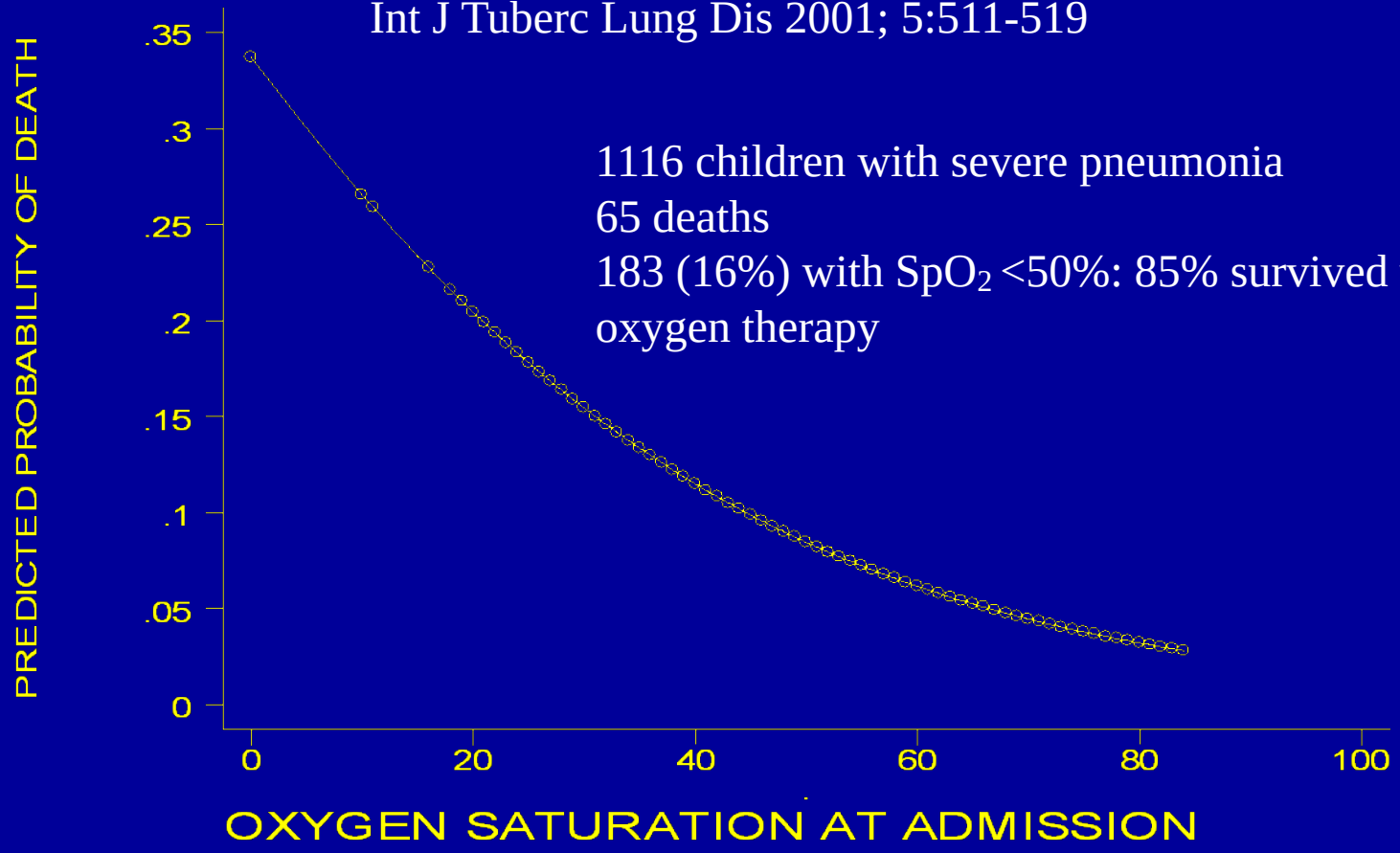
Int J Tuberc Lung Dis 5(6):496-504

When to give oxygen

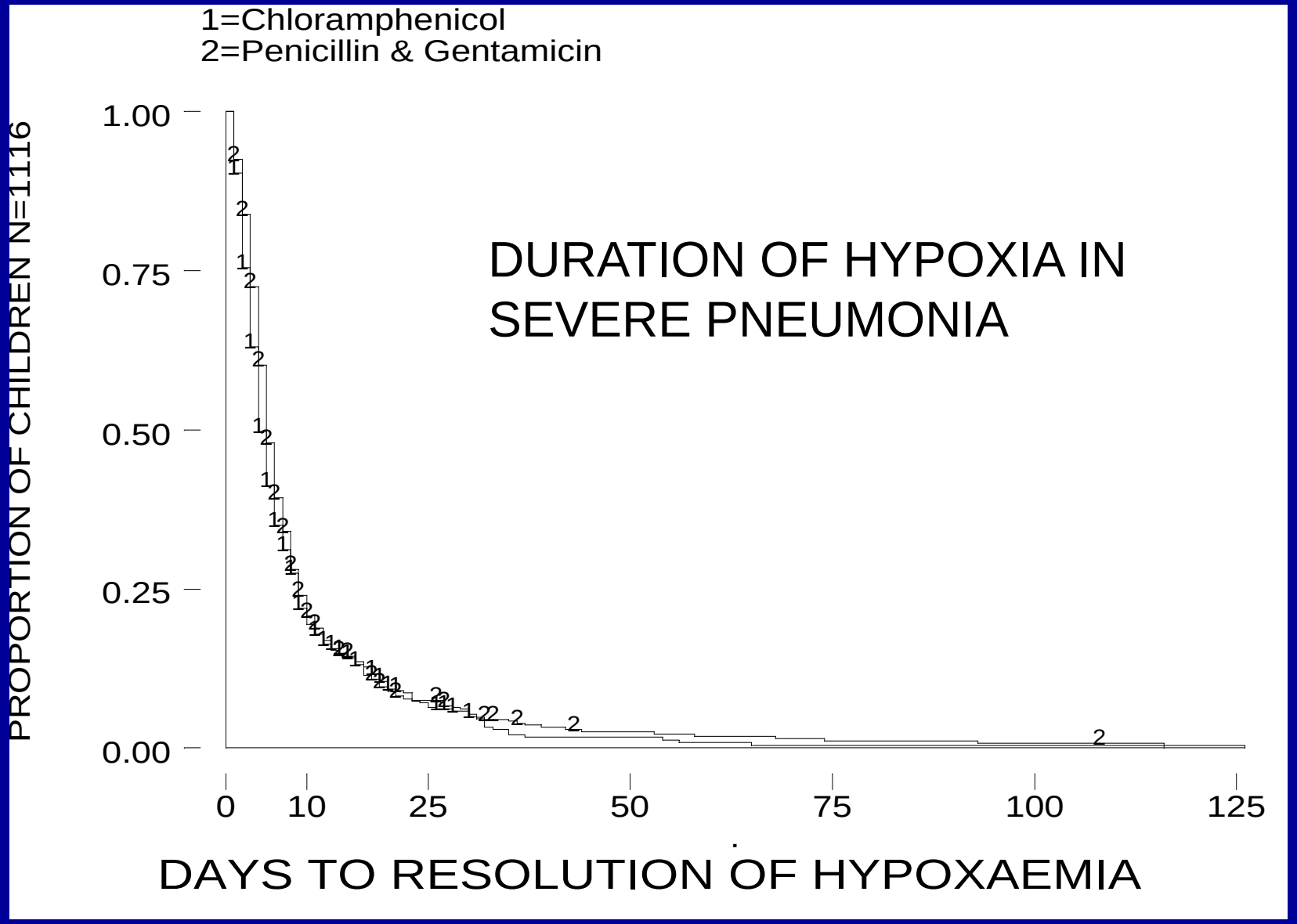
- The normal oxygen saturation (SpO2) at sea-level is 95-100%
  - Children with an SpO_2 less than 90% are hypoxaemic and need to be given oxygen
- At high altitude the normal SpO_2 is lower
  - Oxygen for SpO_2< 90% where supplies are available
  - Oxygen for SpO_2<85% for altitudes >2500m where supplies are limited

Hypoxaemia and the risk of mortality

Int J Tuberc Lung Dis 2001; 5:511-519



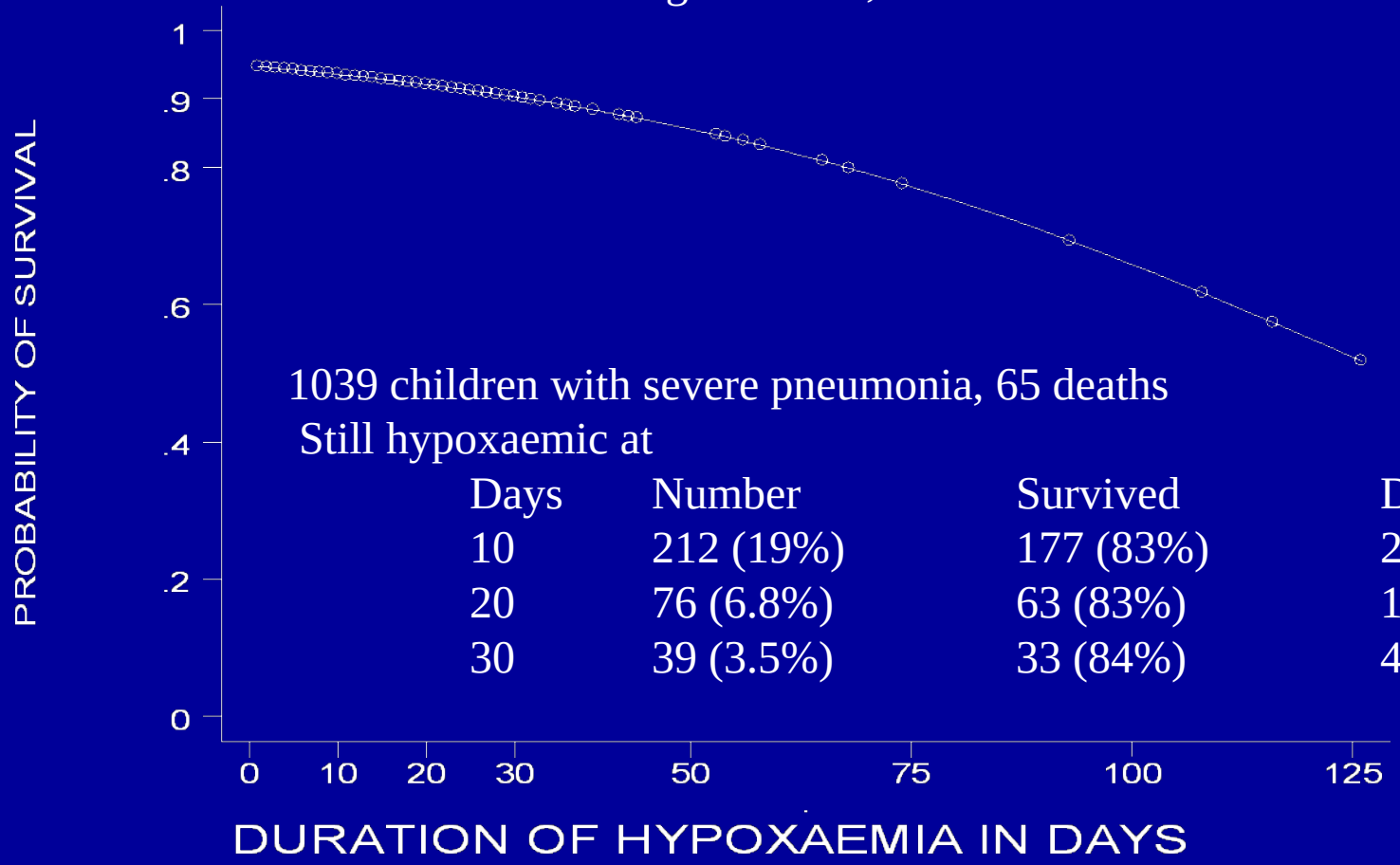
1116 children with severe pneumonia
65 deaths
183 (16%) with SpO_2 <50%: 85% survived with oxygen therapy



Lancet 2002;359:474-480

Duration of hypoxaemia and chance of survival

Int J Tuberc Lung Dis 2001; 5:511-519



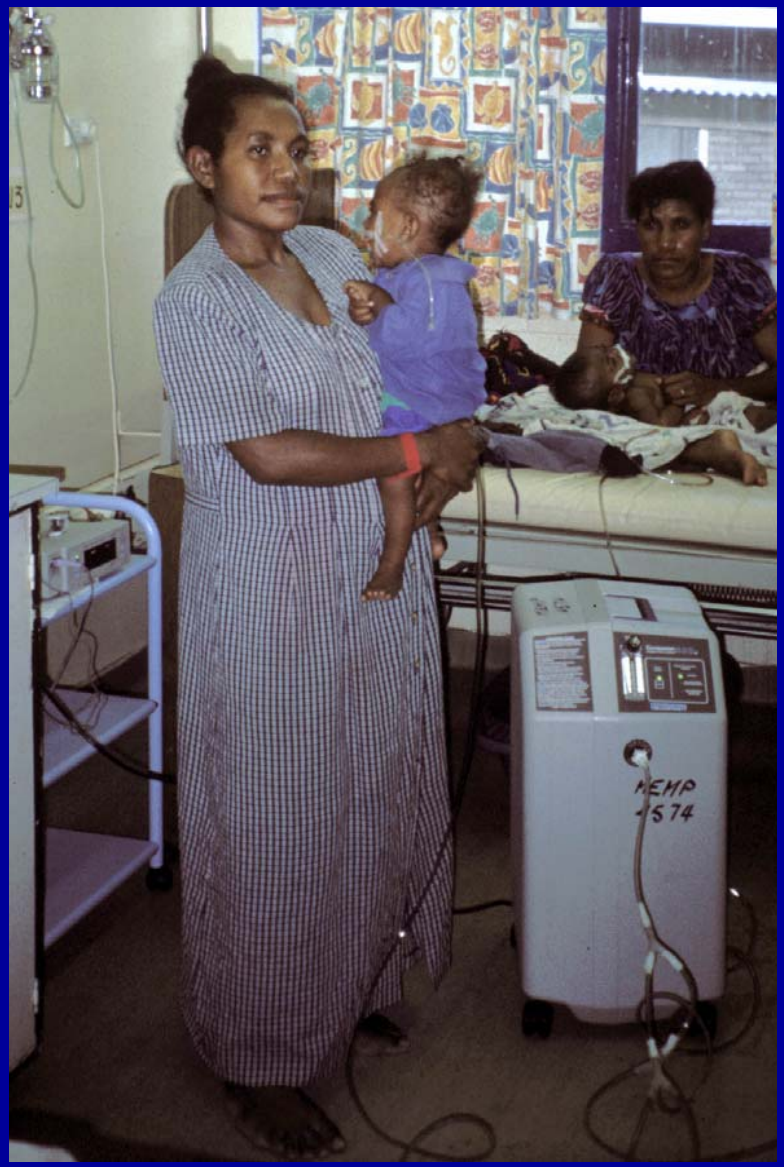
1039 children with severe pneumonia, 65 deaths

Still hypoxaemic at

Days	Number	Survived	Died
10	212 (19%)	177 (83%)	28
20	76 (6.8%)	63 (83%)	10
30	39 (3.5%)	33 (84%)	4

Oxygen systems

- Pulse oximetry
- Oxygen concentrators
- Back-up cylinder
- Continuous power supply
- Oxygen tubing and delivery mechanism
- Protocols for use of oxygen
- Training and supervision
- Maintenance and spare parts
- Follow-up



Clinical detection of hypoxia is difficult

Clinical signs of hypoxaemia are insensitive

Cyanosis	Median SpO_2 68% (51-76%)
No cyanosis	Median SpO_2 76% (70-80%)
Oxygen saturation	**Percentage of children detected to have cyanosis**
SpO_2 <50%	88%
SpO_2 50-69%	81%
SpO_2 70-84%	44%

When to use pulse oximetry

- Pulse oximeters should be used to monitor:
  - Every child or neonate at admission (not just those with pneumonia)
  - During ward rounds and nursing observations to monitor progress
  - Any child who deteriorates with respiratory distress, apnoea or decreased conscious state

How to use pulse oximetry

- Turn the pulse oximeter on
- Have the child sitting comfortably in the parent's lap
- Attach the oximeter probe to the finger or toe of the child
- Wait until there is a consistent pulse signal (this may take 20-30 seconds)
- Record the SpO_2 on a monitoring chart.
- If the SpO_2 is less than 90% the child should receive oxygen

How to use pulse oximetry

- Use nasal prongs or a nasal catheter
- Give oxygen at a flow rate of 0.5-2 litres per minute continuously
- Recheck the SpO_2
- Record the SpO_2 15 minutes after giving oxygen on a monitoring chart

Daily monitoring using pulse oximetry

- At least daily pulse oximetry readings on all children receiving oxygen
- Take the child off oxygen (unless they have severe respiratory distress)
- Monitor the SpO_2
- If the SpO_2 is greater than 90% 10-15 minutes after coming off oxygen, they can stay off oxygen
- Check the child's SpO_2 again in one hour

Daily monitoring using pulse oximetry

- If the SpO_2 is less than 90% the child should go back on oxygen
- Each day record the SpO_2 on the patient's monitoring chart
- Record if there are sufficient supplies of oxygen to give oxygen to that particular child at the time of recording

Daily monitoring using pulse oximetry

- Oximetry should be used regularly to monitor any child who develops worsening respiratory distress, apnoea, any deterioration in consciousness or any other clinical sign of deterioration

Discharge planning

- Pulse oximetry can be used to determine when it is safe to send a child home
- In most circumstances it is unsafe to send a child home when their SpO_2 is less than 90%

Care of a pulse oximeter

- The pulse oximeter finger probes and leads are fragile, so it is important to look after them carefully. They should not be put on the floor or where they could be stepped on
- Keep pulse oximeter probes clean so that they do not spread infection from one patient to another
  - Wipe with an alcohol swab between patients
  - Health workers must always wash their hands before and after monitoring each patient
- Always remember to plug the oximeter into the mains power after every use to recharge the internal battery