Modelling the potential impact of pneumococcal vaccination strategies in humanitarian crises

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Conflict of Interest:
The author has declared no conflict of interest.

Streptococcus pneumoniae (the pneumococcus)

- Common bacteria residing in the human nasopharynx
- Transmitted from person-to-person following close contact
- Occasionally causes disease:
    - Tonsilitis
    - Otitis media
    - Pneumonia
    - Meningitis
    - Sepsis
- Disproportionally affects young children and those with weakened immune systems
- Over 100 known serotypes
- Caused 11% of all <5y mortality in 2015

Pneumococcal burden in humanitarian crises

- Largely unknown
- Increased disease and mortality rates
  - All-cause mortality is frequently ≥2 times pre-crisis baseline
  - Respiratory infections leading cause of mortality in <5y
  - Presence of risk factors relevant for pneumococcal spread

Risk factor	Carriage	Disease	Death
Acute malnutrition	++	+++	+++
Measles outbreaks and other viral RTIs	++	++	++
Overcrowding and altered social contact patterns	+++		
Disrupted routine PCV use	+	+++	
Low access to curative care	+	+	+++
Smoke inhalation		+	
Inadequate water and sanitation	++	+	

Bellos et al (2010); Van Zandvoort et al (2019)

Intervention

- Pneumococcal Conjugate Vaccines (PCV)
  - Safe and effective
  - Protects against transmission and disease of the most invasive serotypes
  - Introduced in most EPI programmes
  - Expensive, but mitigated by Humanitarian Mechanism (+Pneumosil)
  - **Rarely used in crisis settings**

- Little guidance on the use of PCVs in humanitarian settings
  - WHO recommendation on PCV in crises
    - Use in children <1 year
    - Consider in children <5 years
  - Routine immunization often not feasible

World Health Organization (2019)

ESPICC study (2018-2023)

Evaluating Strategies for Pneumococcal Immunization Campaigns in Crises (ESPICC)

- Aim: to identify optimal vaccination strategies for populations affected by humanitarian crises
- Method
  - Ideally cluster Randomized Controlled Trial – but not feasible
  - Alternative study design:

1. **Primary data collection of key model parameters**
   - Contact and carriage patterns
   - Conducted a cross-sectional survey in Somaliland camp for internally displaced people (IDP) in 2019
2. **Mathematical modelling of different vaccination strategies**
3. **Follow-up intervention study**
   - EEPICC study

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Primary data collection

- **Digaale IDP camp, Hargeisa, Somaliland**
- Save the Children International
- Somaliland Ministry of Health Development

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Digaale IDP camp

- Permanent camp, established in 2014
- Population displaced by drought
- 900 shelters
- ~500 households / ~2000 people
- Overcrowding - median household size 4 (2-6) people
- Young population - median age 15 (7-34) years
- High crude death rates
- High migration rates
- Malnutrition - 20% <5y wasted, 30% stunted

Van Zandvoort et al (2021)

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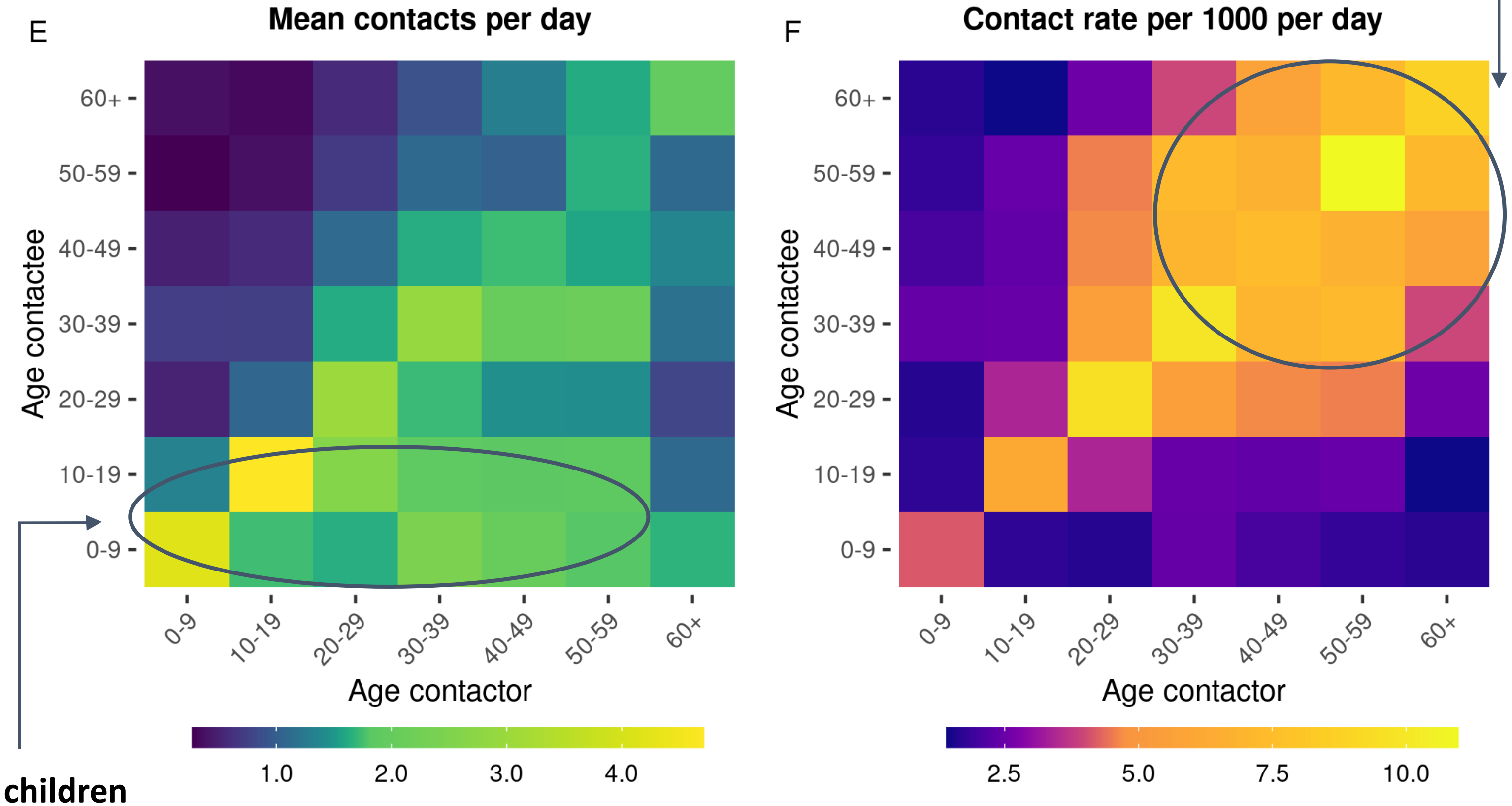
Social contact patterns

Who contacts whom?

- All age groups, ~9-11 contacts per day
- 78% of contacts physical
- Most contacts at home
- Very few contacts at school or work
- Very few contacts outside IDP camp

High levels of intergenerational mixing



Most contacts made by/with children

Van Zandvoort et al (2021)

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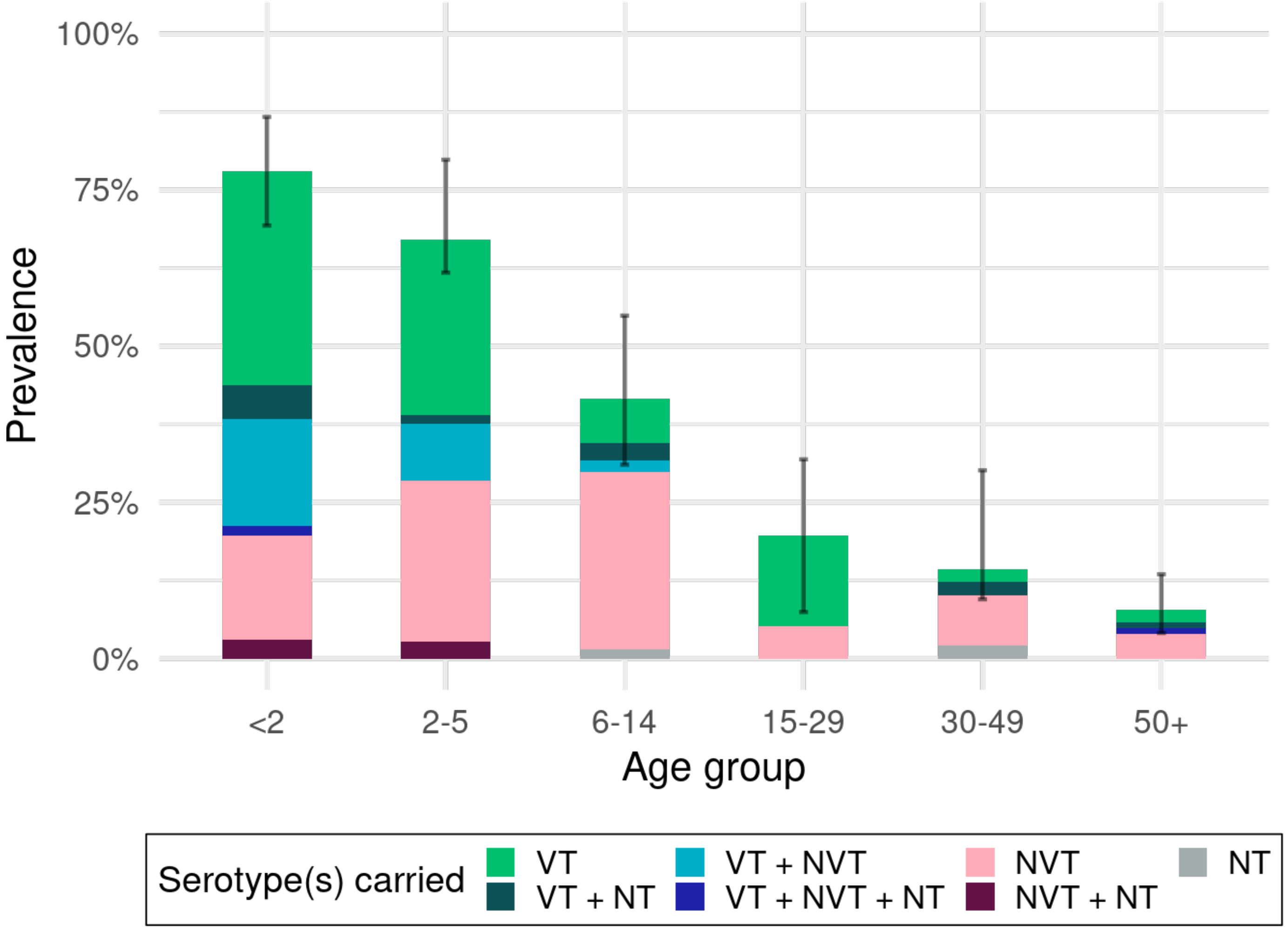
Pneumococcal carriage prevalence

- N_{swabs} = 454

- 45%, tested positive for pneumococcus
- ~50% are VT serotypes
- 75% in children <5 years

- Similar to Kenya, Uganda, Malawi
- Lower than the Gambia



Van Zandvoort et al (Unpublished data)

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Modelling PCV strategies

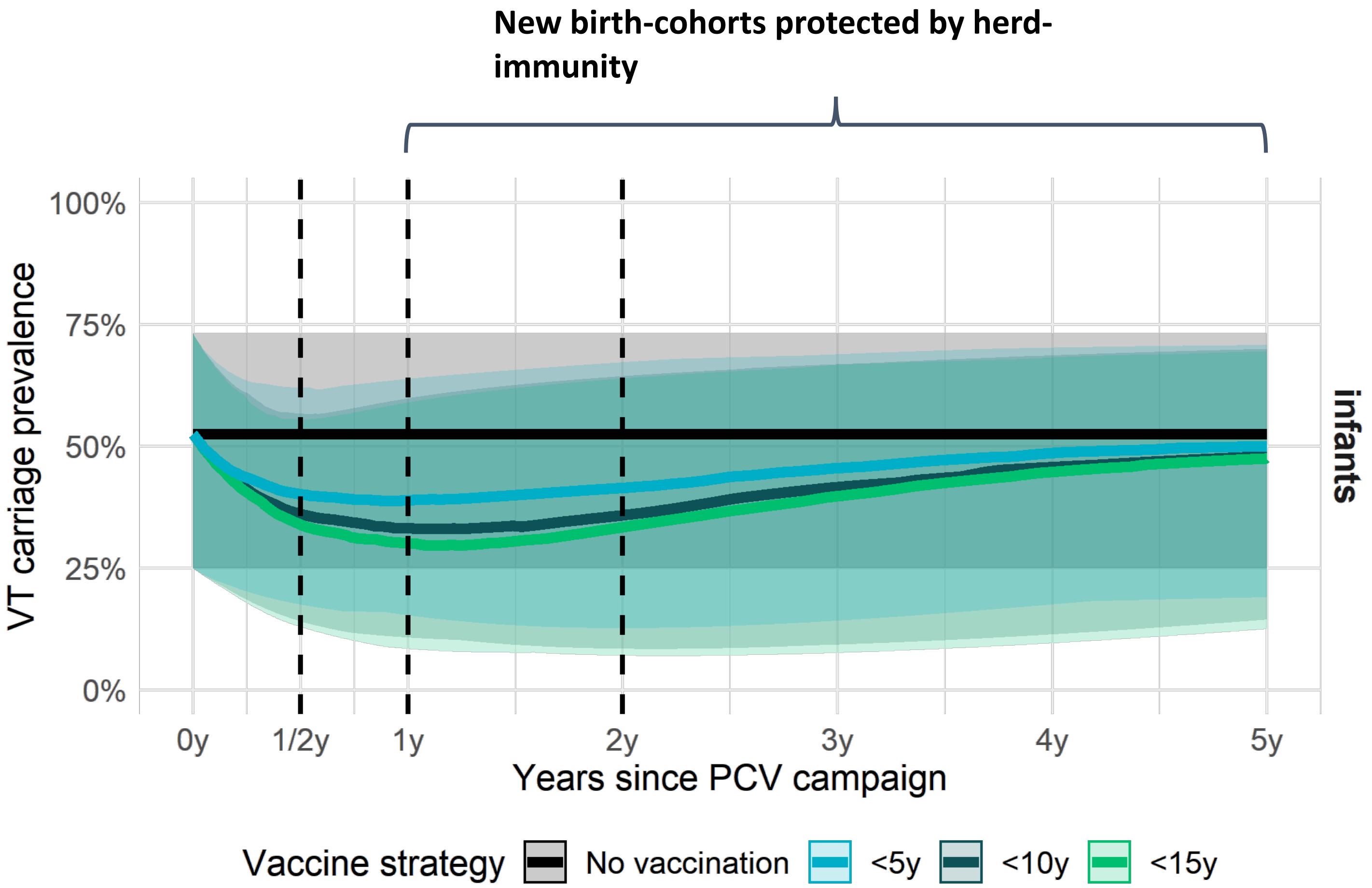
- Transmission model simulates pneumococcal transmission
- Simulate a single PCV campaign, **without routine immunization**
- Aim to **achieve high level of herd-immunity** (against vaccine-targeted (VT) serotypes)

- High vaccine coverage (assume 85%)
    - Modelled PNEUMOSIL
    - Direct protection to those vaccinated
    - Indirect protection to those unvaccinated: herd immunity

- Compare a single PCV campaign targeting children:
    - <5 y
    - <10 y
    - <15 y

Carriage prevalence in infants

- Able to establish partial herd immunity
- Peak impact at ~1 year after campaign
- Larger impact with wider age targeting
- Faster waning with <5y campaign
- Will return to baseline in absence of additional vaccination



Van Zandvoort et al (Unpublished data)

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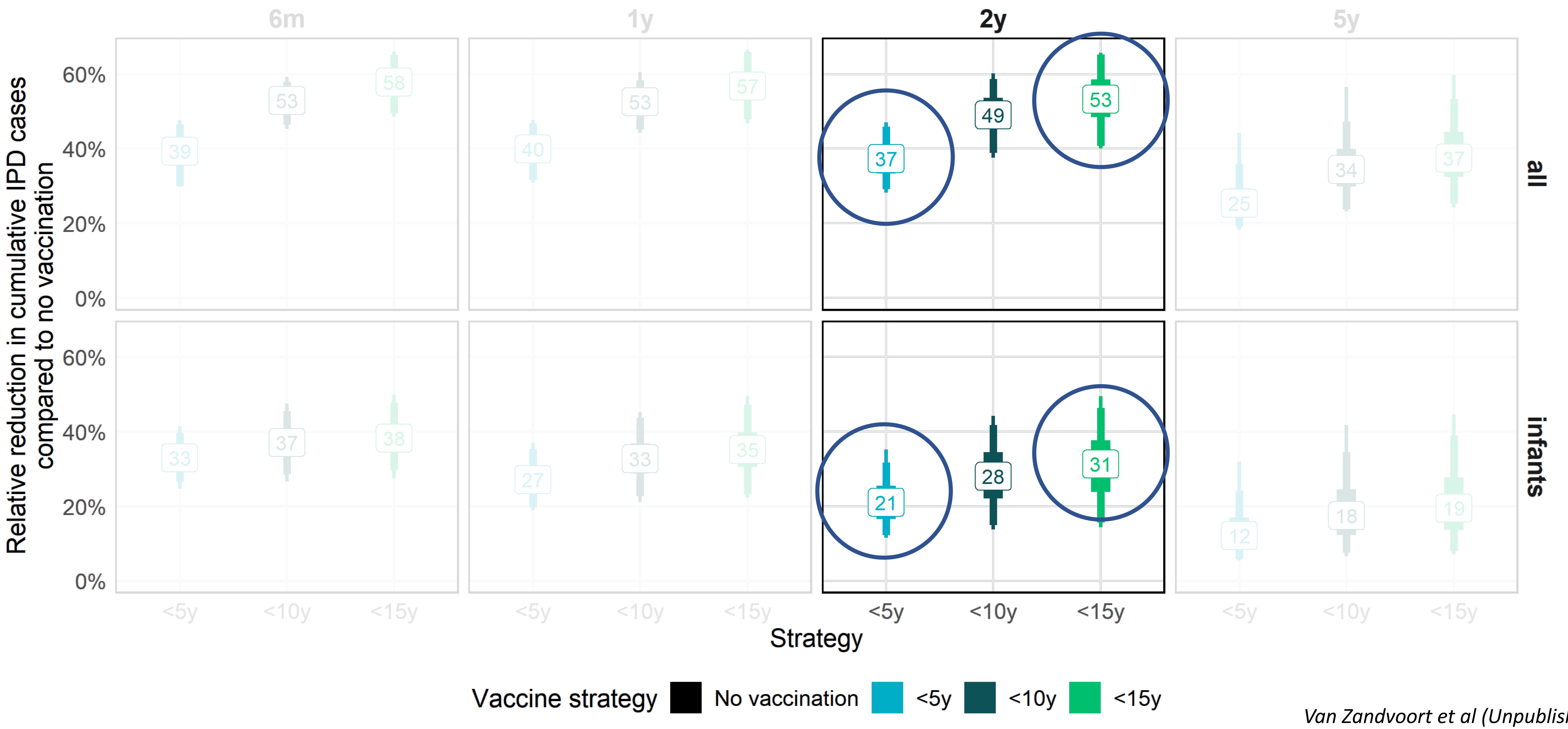
Cumulative impact on invasive pneumococcal disease (IPD) cases



Van Zandvoort et al (Unpublished data)

Modelling PCV campaigns (other settings)

Differ in:
- Demographic characteristics
- Mixing with (unvaccinated) host population
- Migration rates
- Malnutrition rates

Population	Impact IPD (infants; 2y post campaign) – higher is better		Impact IPD (all ages; 2y post campaign) – higher is better		Efficiency (all ages; 2y post campaign) – lower is better	
	<5 campaign	<15 campaign (ratio)	<5 campaign	<15 campaign (ratio)	<5 campaign	<15 campaign (ratio)
Digaale, Somaliland, 2019	18%	28% (1.6)	34%	51% (1.5)	950	1,768 (1.8)
Bentiu PoC, South Sudan, 2015	15%	22% (1.5)	29%	44% (1.5)	1,067	1,682 (1.6)
Bambari, Central African Republic, 2019	15%	30% (2.0)	32%	52% (1.6)	827	1,213 (1.5)
Maiduguri, Nigeria, 2016	14%	20% (1.4)	26%	39% (1.5)	1,404	2,320 (1.7)
Maiduguri, Nigeria, 2019	12%	16% (1.3)	27%	40% (1.5)	1,402	2,273 (1.6)
Overall	**~15%**	**~15 to 30%**	**~30%**	**~40 to 50%**	~900 to 1,400	~1,200 to 2,400

Van Zandvoort et al (Unpublished data)

Conclusions

- PCV campaigns can be effective to prevent pneumococcal disease in populations affected by humanitarian crises (where routine immunization is not feasible)
- Unvaccinated birth cohorts can be partially protected by high vaccine coverage in older children
- Campaigns in <5y achieve good impact in all scenarios – but campaign should be adapted to local epidemiology
- PCV campaigns in crises are efficient use of PCV, if routine use is impossible
  - Multi-antigen campaigns may further improve efficiency, e.g. by combining PCV vaccination with Measles vaccination

Thank you!

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