Table S1. Themes in MNH referral systems in the three study provinces/districts.

Dimensions	Province 1 (P1), District 1 (D1)	Province 2 (P2), District 2 (D2)	Province 3 (P3), District 3 (D3)

Overall functioning	• Perceived to be functioning well, although constrained by structural and emerging challenges, notably
	  o Lack of District Hospital (DH) beds in parts of metro
	  o Staffing setbacks, incl. EMS
		• Perceived to be improving although 'not 100% smooth'
		• MNH referral relationships between PHC and DH functioned unevenly across the district
			• Perceived to be a major challenge, hampered by
			  o critical weaknesses in EMS
			  o referral pathways not fit for purpose

A referral policy/strategy	• Provincial and district policies in place with appropriate forms and documentation, and agreement on referral pathways	• Provincial policy and district standard operating procedures in place, but needed to be (re)negotiated between all key players in each locality to address:
		  o Appropriateness of referrals and distribution of deliveries between CHCs and DHs
		  o Regional Hospital (RH) providing DH services for immediate catchment area
		  o Patient movement across the boundaries of the sub-district, districts and neighbouring provinces through Service Level Agreements (SLAs)
			• Provincial policy in place, but described as 'desk top', unable to address complex realities on the ground, including:
			  o Resource implications of cross border service utilisation, spanning sub-districts, districts, neighbouring provinces and countries (Swaziland, Mozambique)
			  o RH providing DH services for immediate catchment areas
			  o No SOPs enabling bypassing when requisite expertise unavailable at the next level in the referral pathway
			• With support of partners, agreements on referral pathways negotiated in specific sub-districts

Adequately resourced sending and receiving referral facilities	• 'Distorted service delivery platform' as a legacy of apartheid hospital planning
	  o In one sub-district of the metro three hospitals providing regional and tertiary services and no DH
	  o In another sub-district, a DH having capabilities (neonatal ICU, obstetricians) equivalent to next referral hospital, but inadequate support services e.g. blood bank
	• Considerable everyday management (through system brokers) and up-and-down swapping of beds/patients across the platform
		• Perceived imbalance in maternal deliveries between CHCs and DH
		  o 24-hour CHCs staffed with midwives, with potential to do more deliveries but lack doctor support
		  o DH staffed with doctors, but acute shortage of midwives
		• Availability of obstetricians at RH, but similar shortage of midwives and limited beds/physical infrastructure
		• Goal is for a high care neonatal unit in each district hospital able to provide CPAP and presence of motivated/skilled staff, but hampered by availability of essential supplies such as medical air
			• Perceived imbalance in maternal deliveries between CHCs and DH (as in P2)
			  o Successfully negotiated a shift in uncomplicated deliveries towards CHCs in one sub-district
			  o DH staffed with doctors, but acute shortage of midwives
			• Presence of a well-functioning MNH service in one RH, with adequate staffing and recent upgrading of neonatal ICU
			• DH have capacity to provide neonatal high care (e.g. staff, CPAP), but relatively minor bottlenecks in supplies (e.g. piping for CPAP), equipment (e.g. a theatre bed) hampered\ delivery of services

	• Adequate staffing of doctors, but acute shortages in nursing staff, especially midwives at lower levels of the system • Well established midwife obstetric units (MOUs) in the metro, with medical support	• Neonatal ICU in regional hospital, staffed by a paediatrician, but insufficient beds • Appointment of provincial tertiary level specialists with responsibility for supporting lower levels	• RH and TH have overlapping profile of services and competencies, also a legacy of apartheid hospital planning o Scope for rationalisation and agreement on bypassing to quaternary services in other provinces

Functioning emergency medical services (EMS)	• 420 ambulances, ratio of 1 per 15,000 population [interview data, Nov 2022]
	• EMS obstetric emergency urban inter-facility transfer under 30 minutes rate: 44% (2019/20) [National Indicator Data Set]
	• EMS considered largely unproblematic 'within boundaries of the metro'
	• Sufficient vehicles, but staffing an emerging issue
	  o COVID contract posts terminated
	  o National regulations on minimum skill level
	• Enabled though informal relationships between EMS and managers at sub-district level
	• At district level EMS functions as 'an island', reporting to the province
		• 262 ambulances, ratio of 1 per 23,000 population [news report, May 2023]
		• EMS obstetric emergency rural inter-facility transfer under 60 minutes rate: 30% (2019/20)
		• EMS Priority 1 rural obstetric response under 40 minutes rate: 41% (2019/20) [National Indicator Data Set]
		• EMS considered to be reasonably functional at district level
		• Have ambulances stationed at facilities (CHC and hospitals) although still need to go via central EMS call centre
		• Joint manager/EMS WhattsApp groups in emergencies
		• Would like more obstetric ambulances
		• Steps at provincial level to upgrade skill levels of EMS, following national regulations
			• 72 functioning ambulances, ratio of 1 per 65,000 population [provincial parliamentary report, Feb 2023]
			• No routine EMS data reported in National Indicator Data Set
			• EMS source of 'massive trouble', with delays of up to 8 hours for emergency transfers
			• Critical shortage of and inadequately equipped ambulances
			• Lack of competencies in triaging and prioritisation at the EMS call centre
			• No ambulances stationed at health facilities

Communication and collaboration between levels of care	• Weak collaboration and communication between PHC and regional hospitals where no DH intermediary
	• District programme managers and specialists broker relationships and address day-to-day problems between hospitals
	• Lack of feedback on referred cases
	• Clinical managers of all hospitals (DH, RH, TH) in metro have a regular forum and address referral and outreach issues
	• System strengthening through Mphatlalatsane initiatives
		• Relationship between PHC system and DH variable between sub-districts
		• Collaborative relationships between DHs and RH, and between RH and TH improved, through active efforts of district management team
		• District managers, specialist clinicians in district and province, and partners broker relationships and communication between levels
		• Lack of feedback on referred cases
		• Communication hampered by network availability
		• Multiple WhatsApp groups connecting players, including EMS within district and beyond; accelerated with COVID
			• Lack of structured relationships between PHC system and DH managers
			• Collaborative relationships between one RH and DHs in the referral 'wedge' improved with support and brokerage by partners
			• Lack of structured relationship ('interdepartmental forum') between managers at RH and TH
			• District clinical specialist, programme managers and partners broker relationships and support system strengthening, but lack
			  o jurisdiction over RH and TH
			  o authority to improve supply chains
			• Plans to introduce a national m-health referral app, Vula

		• Provincial level Neonatal Response Team, builds relationships between TH and RH, incl. in referral of individual cases	• RH established a forum for nursing managers in catchment area, including DH, PHC and EMS • Clinical managers meet regularly in a provincial forum, negotiate sharing of specialised clinical resources across platform

Table S2. Themes in MNH outreach systems in the three provinces/districts

Dimensions	Province 1 (P1), District 1 (D1)	Province 2 (P2), District 2 (D2)	Province 3 (P3), District 3 (D3)
Model	Combination of: • District Clinical Specialist Team (DCST) evolving into regional and provincial level specialists • District and sub-district programme managers • Facility outreach within PHC system (mid-wife obstetric units (MOUs) to clinics) • Weak role of tertiary hospital	Combination of: • Cascade model from regional hospital specialists to district hospital generalists to PHC • Central (provincial) coordination by tertiary level specialists in obstetric and neonatal 'response teams' • District and provincial programme managers • Provincial partner for newborn and maternal health	Combination of: • DCST plays major role (5 members)* • District and sub-district programme managers • Regional hospital outreach • Facility clinical managers • District PEPFAR partner supports in-service training
Clinical care and mentorship	• DCSTs run specialist outpatient clinics at district hospital, and provide telephonic support • No outreach from tertiary hospital • Advanced midwives in CHCs support PHC clinics	• Regional hospital specialists see 'cold cases' at district hospitals • Tertiary level provides telephonic support through provincial response teams • Uneven support for PHC from district hospitals	• Regional hospital obstetricians support MOUs in surrounding sub-district • DCSTs do limited clinical work • Uneven support for PHC from district hospitals
In-service training	• Skills development plans at facility and sub-district level developed • Established Regional Training Centre (RTC) • Programme manager and DCST agree training targets with RTCs	• Training infrastructure and support through university partner for newborn health • Virtual and face to face programmes through the response teams • On site skills development and mentoring (surgical and anaesthetic)	• Annual 3-week programme of skills development for community service doctors arranged by DCST • Relies on clinical manager initiative in district hospital • Programme managers organise training for PHC
Audit, M&E	• Facility audit tools developed by programme manager • Perinatal mortality meetings conducted within facilities • Confidential enquiries into maternal deaths • Quarterly general clinic assessments (Ideal Clinic programme) • Operational managers meet monthly in each sub-district to review indicators, and quarterly at district level as part of routine performance reviews • Lack of MNCH specific district forum and loss of district programme staff	• Performance Monitoring and Response Forums (PMRF) meet monthly in catchment areas of sub-districts and district, with a focus on MNCH o Conduct real-time maternal and neonatal mortality surveillance and appropriate responses • Provincial-level maternal death audits • Provincial Maternal Health Standards launched in 2019 • Facility Assessment Tools (FAST) for neonatal care developed by support partner	• Programme managers and DCST conduct facility audits and district reviews • Joint PHC, district hospital perinatal mortality review meetings • Confidential enquiries into maternal deaths • Vula app provides opportunity for systematic collection of data on referral system • General district quarterly review processes

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