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Defining and responding to the contextual drivers for implementation of antimicrobial stewardship in 14 neonatal units in South Africa

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Background: Research on the contextual drivers of antimicrobial stewardship (AMS) programme interventions in neonatal units is limited.

Methods: As part of a prospective mixed-methods multidisciplinary neonatal AMS (NeoAMS) interventional study in 14 South African hospitals, we applied a three-phased process to assess implementation barriers and contextual drivers experienced by participating health professionals. The study included: (Phase one; P1) a survey of pre-intervention barriers and enablers; (P2) written feedback during the study intervention phase; and (P3) semi-structured exit interviews.

Results: Respondents to the P1 survey ($n=100$) identified 15 barriers, 9 in the domain of personnel resources, including staffing, time and workload constraints. Other barriers related to limited access to antimicrobial use and surveillance trends, complexity of neonatal care, absence of multidisciplinary team (MDT) AMS and change resistance. For P2, written feedback during implementation ($n=42$) confirmed that the MDT approach facilitated systems changes, including policy adaptations, process improvements, strengthened infection control practices, and expansion of AMS MDT roles. MDT benefits were described as aligned team purpose, improved communication, and knowledge sharing. Reported challenges included time to meet and building trust. In P3 interviews ($n=42$), improved interpersonal communication, trust, personal growth and confidence building were cited as highlights of working in multidisciplinary AMS teams. Extending the MDT approach to other hospitals, training more health professionals in AMS and increasing management involvement were identified as priorities going forward.

Conclusions: Understanding the organizational and interprofessional context for NeoAMS implementation enabled an MDT approach to develop and optimize neonatal AMS with potential for adoption in similar resource-constrained settings.

Introduction

Reports from South Africa indicate that antibiotic-resistant infections are now the leading cause of late neonatal mortality, with documented resistance to multiple antibiotics observed in neonates with sepsis.[1–4] The implementation of antimicrobial stewardship (AMS) programmes in neonatal wards and neonatal ICUs (NICUs) is crucial, particularly given the extended hospital stays and heightened risk of healthcare-associated infections (HAIs) in preterm and low-birthweight infants.[1,2,5,6] In South Africa, this implementation is further challenged by a scarcity of specialist neonatologists, paediatric infectious disease (ID) specialists, a lack of formally trained ID pharmacists, and inadequate numbers of onsite microbiologists. There is a pressing need to develop and deploy AMS interventions within hospitals, using resources currently available.

Our previous studies highlighted the crucial role that pharmacists play in initiating AMS.[7–11] It is recognized that for AMS to be sustainable and effective, they must rely on teamwork by multidisciplinary teams (MDTs). This requires collaboration among various healthcare professionals to overcome challenges, implement interventions, and develop the necessary organizational infrastructure. Given the specialized nature of neonatal care and the knowledge gap among non-ID-trained pharmacists in South Africa, there is a need for more formalized support structures.[11,12]

Furthermore, robust evidence is needed to support the successful implementation of AMS interventions. This is integral to adequately inform AMS in different environmental and cultural contexts and to understand how effective interventions can be sustainably adopted.[13,14] Whilst there is increasing recognition of the value of qualitative research,[13,15–17] most AMS interventions lack integration of qualitative and social sciences, resulting in a gap in their effective implementation and adoption.[18]

To the best of our knowledge, there are no published qualitative data mapping the implementation process of neonatal AMS interventions in Africa.[19] Of note, besides a recent qualitative study that included private hospital neonatal units in India that highlighted how doctors' perspectives of the risks of AMR in neonates influence antibiotic prescribing, no data from low- and middle-income countries (LMICs) is available.[20] Most qualitative evidence synthesis of key AMS barriers, enablers and acceptability assessments in paediatric and neonatal care settings have emanated from high-income countries.[21] Only a few have reported qualitative evidence performed in NICUs.[22–24]

We report on the implementation of a neonatal AMS intervention (NeoAMS) in heterogeneous, geographically disparate and resource-limited settings across 14 South African hospitals.[25] In developing the NeoAMS intervention, we recognized that an effective neonatal AMS programme would depend on the formation of functioning MDTs, involving multiple healthcare professionals collaborating to implement AMS interventions. The design of the study as a multicentre collaboration using the Breakthrough Series[26] method with progressive shared learning and feedback sessions (LFSs) provided an opportunity for qualitative research and thematic analysis.

Aiming to strengthen MDT commitment, inform programme expansion and ensure sustainability, we conducted a nested

three-phase qualitative study to examine barriers and enablers and describe the contextual drivers of MDT involvement during NeoAMS implementation in resource-constrained neonatal units.

Methods

Study setting and site selection

The qualitative study was conducted during a sequential three-phase, mixed-methods, multidisciplinary, prospective NeoAMS intervention in 14 South African hospitals (7 public, 7 private) across six of the nine provinces from February to November 2022. Of the hospitals, 6 were tertiary academic institutions, 11 were urban and 3 were rural.

Overall NeoAMS study design

The NeoAMS audit-and-feedback intervention and outcomes used are described in detail in a separate publication.[25] Briefly, the study faculty members were recruited by the study investigators and comprised specialist neonatologists and clinical microbiologists from the South African National Neonatal Sepsis Task Force (NNSTF), pharmacists, professional nurse leaders in South Africa, and four international advisors with expertise in AMS programmes, neonatal infections and qualitative research. One of the study investigators served as the project manager (PM). Hospitals and associated healthcare workers were recruited by the study faculty through e-mail and telephonic circulation of an open 'call to participate' in the study using their wide professional network.

The NeoAMS faculty collaboratively designed the study protocol, surveys and data collection tools, and supported the completion of health research ethics applications and hospital approvals. Each participating hospital nominated a MDT of health professionals comprising one or more of each of the following: pharmacists; neonatal doctors (neonatologists/paediatricians); clinical microbiologists; and neonatal nurses. The AMS intervention using a multidisciplinary collaborative method known as the Breakthrough Series[26] incorporated online, real-time AMS training and progress feedback sessions using standardized templates, weekday pharmacist audit of neonatal antibiotic prescriptions with real-time, face-to-face feedback, and AMS recommendations given to the treating clinician and the MDT.

Qualitative study design

The methodology (design, process, data collection and analysis) for assessing qualitative components of each phase of the study was completed by the NeoAMS faculty.

In Phase one (P1), a pre-intervention cross-sectional electronic survey was conducted in February 2022 to identify contextual barriers, enablers and drivers for implementation of neonatal AMS (Table S1, available as Supplementary data at *JAC-AMR* Online). The categories included personnel resources, data access (e.g. microbiology, antibiotic consumption), system barriers, knowledge and competence, neonatal unit culture, and information technology infrastructure.

In Phase two (P2), during the neonatal AMS implementation, three sets of written feedback were received in May, June and July 2022, each following standardized questions (Table S2) about the intervention process and functioning of the MDT team at each hospital. Questions included descriptions of system changes, benefits and challenges of working as an MDT, gains and learnings, obstacles and setbacks, improvement opportunities, changes in MDT roles and future prospects. The templates provided for feedback from all members of the MDT and responses were collated by a pharmacist or another member of the MDT team at each hospital.

In Phase three (P3), post-implementation exit interviews were conducted in November 2022 by the PM with MDT members within professional groups (pharmacists, nurses, neonatologists and clinical microbiologists), using a semi-structured interview guide. Four questions aligned to the study objectives formed the framework of the interviews: (i) what motivated you to participate in the study?; (ii) what were the highlights of working in a multidisciplinary neonatal AMS team?; (iii) what were the challenges of working as a multidisciplinary neonatal AMS team?; and (iv) what opportunities do you see for neonatal AMS going forward?

Data collection

Surveys (P1) were completed via an e-mail link, with anonymous responses entered directly into the REDCap database hosted on the University of Pretoria, South Africa server. Designated pharmacists, as central contact persons for each hospital, were asked to remind members of the team at least once to complete the survey within a 14 day deadline. For P2, the content of responses to standardized questionnaires were copied verbatim into an Excel workbook, with a sheet for each question covering all responses listed by each hospital. Hospital names were anonymized, and each hospital categorized as public or private. In P3, 10 semi-structured group interviews were recorded and transcribed verbatim by an independent trained transcriber. Participants and references to facilities were anonymized and participants were coded by professional group and as private or public sector.

Data analysis

In P1, the 'barrier' ratings were grouped as: 1–3 (no/low barrier) and 4–5 (important barrier). Non-response and 'don't know' (DK) were grouped as DK. The χ^2 test, as used to assess the relationships between survey responses and group (hospital sector, neonatal unit size, and profession group), clustered by hospital. Data analysis was carried out using SAS Windows version 9.4. Free-text responses to the enablers question were collated using Microsoft Excel and common words and themes identified.

In P2, the collated data from each hospital to the standardized questions for each of the three LFSs were grouped into themes and subthemes with supporting quotes from the transcribed feedback slides. Data were analysed by the PM with support from the members of the faculty using descriptive content analysis.

In P3, the interview data were analysed by manual open coding of key phrases from the transcripts to determine themes from within the narratives of the interviews. Two interview transcripts were coded by five members of the faculty, followed by discussion and consensus on the coding framework facilitated by the PM. Following this, the framework was used to code the remaining transcripts. Related topics were grouped, and descriptive words used to identify emergent themes and subthemes related to the interview question framework with supporting participant quotes.

Ethics

Participation was voluntary and confidential, and no remuneration was offered to participants. The 100 participating health professionals (NeoAMS Study Group) all signed informed consent forms agreeing to provide survey responses and including permission to record the LFSs and conduct and transcribe exit interviews. Primary ethical approval was obtained from the University of Cape Town Human Research and Ethics Committee (UCT HREC; Ref 446/2021) and reciprocal approval obtained from the relevant HREC at each of the participating sites. All data collected from patient records were anonymized and names of institutions and health professionals removed from all transcripts.

Results

The following subsections reflect the findings from each of the three qualitative components of the study before integrating the findings as part of the mixed-methods design.

Phase 1: Barriers and enablers survey

Responses received from 100 health professionals and leaders were equally distributed between public and private sector hospitals. Demographics of participants are summarized in Table S3. There was a higher proportion of nurse respondents and a lower proportion of neonatal doctor respondents from hospitals with smaller neonatal units (<30 beds). The top 15 key barriers for all respondents across all professions are summarized in Figure 1, ranked by order of importance. Nine of the top 15 barriers were in the domain of personnel resources, related to time (55/100), workload (53/100) and insufficient staff resources (50/100).

Two of the most frequently reported barriers for all respondents were in the domain of data resources. Specifically, no or insufficient data on antibiotic use trends over time (42/100) and lack of access to antibiotic/microbiology data, even if available, to MDTs (40/100) were identified. The complexity of neonatal care in the domain of knowledge and competence was the third highest barrier (51/100). The main themes from the open question on top enablers for neonatal AMS were more staff resources, better communication and strengthening of MDT collaboration. Ranked barriers for all categories (personnel resources, data access, system barriers, knowledge and competence, neonatal unit culture and information technology infrastructure) are detailed in Figure S1.

Phase 2: Implementation phase

Written feedback on standardized questions submitted by each hospital during the implementation phase on behalf of the MDT participants ($n=42$) was thematically analysed and results grouped into system changes implemented, benefits and challenges of working as an MDT, gains and obstacles overcome, and opportunities and future prospects for neonatal AMS (Table 1).

Working as an MDT facilitated common systems changes across hospitals, including policy changes, process improvements, strengthening of infection control practices, and expanding roles of different members of the MDT. Benefits experienced by MDTs included aligned purpose, improved communication and knowledge sharing, while challenges during implementation included insufficient time, organising meetings, staff resources and building trust between team members.

As the study progressed, MDTs reported AMS role changes across different professionals, and enhanced collaboration between members, with MDTs developing ways to overcome obstacles and improve AMS processes. Table 2 details changes in roles of MDTs by discipline. MDT functioning improved as all hospitals reported expanded roles of members of the MDT in NeoAMS with key themes of improved awareness, more ease with interdisciplinary engagement, and better communication.

Improvements suggested included more participation by the team members, as well as strengthening AMS practices such as infection prevention, antibiotic administration (dosage, time and dilutions), diagnostic elements such as optimal use of culture specimens, and establishing NeoAMS as an arm of current AMS committees. Themes for sustainability centred around further education and training, expanding the teams to include more professionals, continuing to use the tools and structures created during the study, and a NeoAMS orientation programme for new staff and interns.

Phase 3: Exit interviews

Thematic analysis of the exit interviews ($n=42$ respondents) by professional group is summarized in Table 3. Motivating factors for participation across professional groups were opportunities (learning AMS and expansion of adult AMS programmes to neonatology), and building relationships (interaction with other

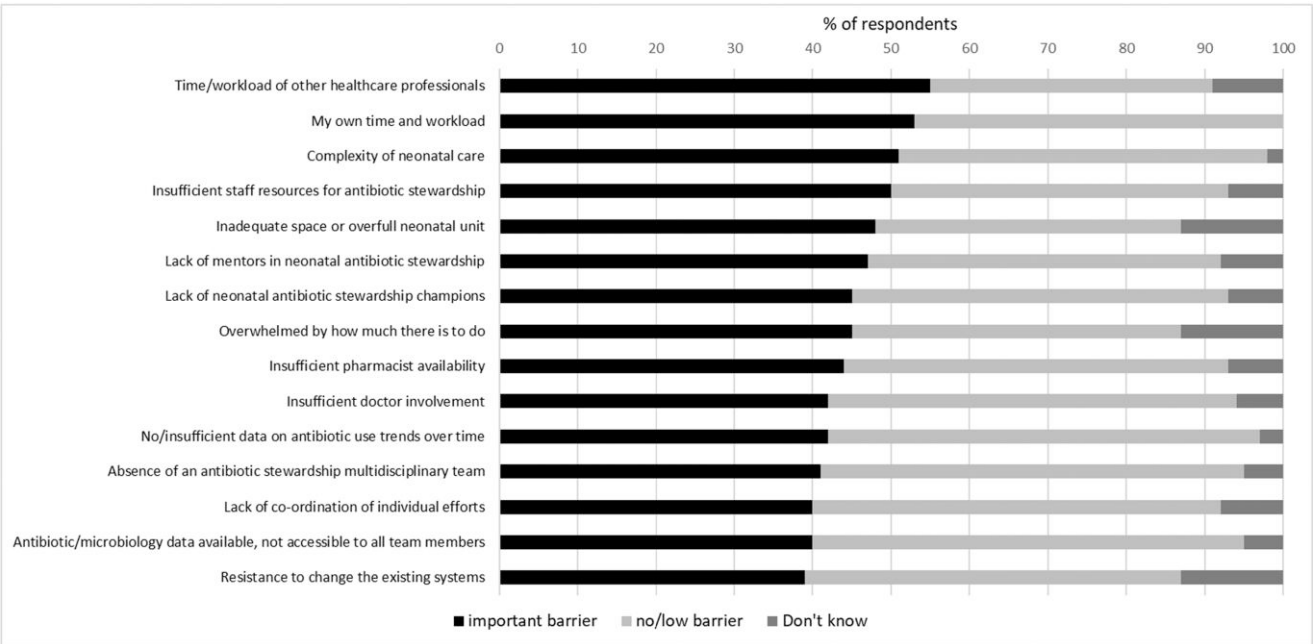

Figure 1. Pre-implementation barriers to neonatal AMS reported by multi-disciplinary neonatal AMS teams across 14 hospitals in South Africa ($n=100$ respondents).

Table 1. Phase two summary of reported systems changes, benefits and challenges of MDTs, and gains and obstacles overcome during the implementation and sustainability and future prospects of the NeoAMS study across 14 public and private hospitals in South Africa

System changes implemented

Revision of antibiotic policy.
New AMS diagnostic policy on PCT & CRP.
Antibiotic chart tailored for neonatal stewardship and including time of prescription and stop date.
Improved source control and infection prevention policy.
Strengthened infection control interventions.

Benefits and challenges of working as a MDT

Benefits	Challenges
Opportunity for knowledge sharing.	Time challenges.
Multidisciplinary alignment of purpose in patient outcomes.	Meeting coordination.
Improved interdisciplinary communication.	Staff resources, rotation, leave and turnover.
Improved relationships between team members.	Building trust between team members.
Facilitated agreement on changes to policies and protocols.	

Gains and obstacles overcome

AMS gains	AMS obstacles overcome
Prescription times improved.	Empowered study members raised queries on prescribing practices in the neonatal unit.
Prioritized MDT weekly rounds.	AMS team WhatsApp group enabled easier communication.
Inclusion of the pharmacy team in neonatal stewardship.	Understanding of the processes at NNU.
Collaborative work between different disciplines	Structure and common purpose helped build better relationships and being willing to listen to all team members.
Increased awareness among clinicians of importance of AMS.	Collecting data on neonatal stewardship.
Rapid access to specialist expertise in the hospital.	Using video to include clinical microbiologists in ward rounds.
Improved time to administration compliance.	

Sustainability and future prospects

Plans for AMS sustainability	Future neonatal AMS prospects
Sustain MDT neonatal AMS rounds and meetings.	Improving or adapting existing policies.
Reinforcing protocols (SOPs) and add to these.	Make AMS more visible around the hospital.
Continue with the AMS WhatsApp group.	Extending AMS ward rounds to the post-natal maternity units.
Train more pharmacists in neonatal AMS.	Engaging in more collaborative projects.
Strengthen the IPC measures in the unit.	Improve the quality of interventions.
Involve more representatives from different disciplines, e.g. paediatricians, pharmacist interns.	Training junior and new staff in all disciplines.
	Collation of all organisms in the NNU.
New staff and intern orientation programme to include NeoAMS and not just AMS.	Address duplicate cover.
	Analysis of local data that have been collected.
Strengthen use of neonatal-specific antibiotic prescription chart.	More participants in the NNU AMS ward rounds.
	Address staff shortages.

AMS, antimicrobial stewardship; PCT, procalcitonin; CRP, C-reactive protein; MDT, multidisciplinary team; SOP, standard operating procedure; IPC, infection prevention and control; NNU, neonatal unit.

professionals, elevating the voice of nurses) to strengthen AMS. Highlights of working as part of an MDT related to improved interpersonal communication and trust, personal growth and building confidence. MDT challenges reported were similar to those identified in P2 related to finding time to meet given the very busy professionals' schedules. Themes relating to opportunities for neonatal AMS going forward were to formalize and standardize the programme to facilitate extension to other hospitals, including peripheral, non-specialized hospitals. Training more pharmacists and incorporating infection control nurses in the team were deemed important programme additions, as was enabling a more inclusive approach to make it accessible to all health professionals, not just AMS experts.

The roadmap of overall qualitative findings in implementation of the NeoAMS intervention is depicted in Figure 2. The Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist is included in Table S4.

Discussion

This study draws on the experiences of multiple stakeholders during the implementation of a neonatal AMS intervention, including

Table 2. Phase two summary of reported changes in AMS roles by professional discipline during implementation of the NeoAMS study across 14 public and private hospitals in South Africa

Reported changes
Pharmacists
Better understanding of neonatal stewardship and importance
Shifted approach to focus on specific neonatal AMS interventions
Actively engaging with prescribers and nurses
Education and training on upholding protocols
Understand the pharmacodynamics in neonates
Empowered to read up and learn more on neonatal stewardship
Better understanding the workflow process and prescribing habits in neonatal units
Now part of the MDT and our expertise on antibiotics can be effectively used in the clinical setting
Nurses
Better interpretation of blood cultures
Improved knowledge about the different organisms
More aware of the role of nurses in neonatal infection control
First to pick up the clinical warning signs of sepsis
Role in administration of antibiotics on time
More aware of AMS and the role nurses can play
AMS round attendance improved
More approachable towards pharmacy
Better communication all round
Knowledge gained has empowered nurses to make meaningful recommendations to the clinicians
Neonatologists/paediatricians
Surveillance system enabled more vigilance with antibiotic use
Abiding by infection control guidelines and protocols
Critically evaluating the indication and choice of antibiotics used
Improved use of antibiotic prescription chart correctly
Able to request input from other disciplines in real time
More open to change and new learning opportunities
Improvement in good working relationships with microbiologists and pharmacy
Clinical microbiologists
Better understanding of the challenges facing sepsis diagnostics in a neonate
Improved interaction as a team and in engaging with paediatricians
Clarity about patients and culture results sorted in the meetings
Participation in AMS ward rounds allowed for involvement of all the role players
Pharmacists are more comfortable to engage with microbiologists
Small opening for clinical microbiologists' role in neonatal stewardship, but not yet fully utilized.

neonatal physicians, neonatal nurses, pharmacists and clinical microbiologists. While neonatal qualitative data have traditionally focused on individual professional groups, surveying all stakeholders within an MDT, particularly regarding the involvement of clinical microbiologists, remains notably uncommon.[27] Our study was designed to include a wide range of participant disciplines across diverse contexts in 14 geographically disparate, urban and rural, academic and non-academic hospitals in South Africa. This approach enabled a comprehensive comparison of the collected evidence.

Our study identifies key insights and narratives, highlighting the barriers, enablers and contextual drivers of MDT engagement that contribute to a successful NeoAMS intervention. The major themes identified centred around structural barriers and organizational context (resources and data access), neonatal knowledge, unit culture and MDT collaboration and communication. Subthemes related to organizational barriers included resource allocation, such as insufficient staff dedicated to AMS, inadequate pharmacist availability, and limited clinician involvement. Time constraints due to heavy neonatal unit workloads further hindered consistent engagement and the implementation of changes. These findings align with Quinn *et al.*,[22] where time was also identified as a major barrier. Other organizational barriers included a lack of coordination in individual efforts and the absence of neonatal AMS champions and mentors. The presence of such champions is crucial, as they help reduce resistance to AMS recommendations and enhance buy-in, as previously reported.[22,23]

Structural barriers included challenges in data access, such as the absence or insufficiency of antibiotic use rates and trends, the lack of antibiograms and antibiotic susceptibility data, or instances where such data existed but was not shared or accessible to team members. Monitoring antibiotic use rates and pathogen resistance trends using available data, setting targets for improvement, and describing susceptibility patterns to enhance treatment guidelines are considered core elements of any AMS programme.[24] Antibiograms, which provide a localized summary of antibiotic susceptibilities for prevalent bacterial pathogens, have been shown to improve antibiotic use, appropriateness and costs.[28]

Participants identified significant barriers in the domain of knowledge and competence, particularly among pharmacists, with a substantially higher proportion of pharmacists indicating this as an important barrier compared with nurses. This finding contrasts with other paediatric and neonatal studies, where nurse participants expressed a knowledge gap and a need for formal training, including terminology and management strategies related to AMS.[21–23,29–31] In our study, specific barriers included a lack of neonatal expertise, the complexity of neonatal care, and the challenge of applying adult AMS concepts to neonates, as previously cited by Canty *et al.*[23]

Despite these challenges, there was a clear desire for collaborative learning within our neonatal MDTs, where stakeholders could share knowledge, experiences and best practices, similar to other reports.[25,32] Such an environment is crucial for enhancing the effectiveness of AMS interventions. By fostering a culture of collaboration and continuous learning, participants can collectively address challenges, innovate solutions and ensure the sustainability of interventions. Consistent with previous reports, unit-level cultural barriers identified in this study included feeling overwhelmed by the extensive demands of the role, a lack of interprofessional relationships, communication barriers[29] and resistance to changing existing systems.[23] In this regard, Qureshi *et al.*[24] recently demonstrated, through a learning collaborative involving 30 Californian NICUs, how openness to change in AMS practices among NICU prescribers can be successfully achieved.

Table 3. Phase three exit interviews with healthcare worker participants in all 14 participating hospitals in the NeoAMS study in South Africa thematically summarized by professional discipline (10 group interviews; 42 participants)

Questions and resulting themes and quotes		Pharmacists ($n=14$)	Nurses ($n=8$)	Neonatal clinicians ($n=5$)	Clinical microbiologists ($n=11$)
What motivated you to participate in the study?	Themes	Learning opportunities to expand their roles.	Wanting to be part of something important.	Opportunity to reflect and review the AMS programme with the enhanced MDT.	Opportunity to expand AMS from adults to neonates and be part of improving AMS.
		Strengthen AMS through involving the full MDT and building relationships.	Interact with other professionals to improve AMS and elevate the voice of the nurse.	Strengthen operations through engagement with the MDT.	Build relationships to strengthen AMS.
	Quotes	*I just wanted to learn more and to be part of the multidisciplinary team. It provided that opportunity. Even though we had some challenges.*	*Breaking down those silos and working collaboratively with the pharmacy team and with the microbiology team, that's key. And through this collaboration it gives nurses a voice. Because very often nurses are just, we're just there. And we do what we have to do, and we get on with the day, and it's almost like the voice of the nurse is not heard.*	*This gave us an opportunity to reflect again. But most importantly, working as a team and with reconnecting with micro again, and pharmacy and everybody was also an opportunity to enhance the team approach to clinical care.*	*The whole area or the arena of neonatal stewardship was very underdeveloped. And it was important to get a neonatal stewardship programme going and let us look at all the challenges that we encounter and what we need to make a success of a paediatric programme.*
What were the highlights of working in a multidisciplinary team (MDT)?	Themes	Having direct communication links to all members of the MDT.	Building relationships to improve AMS.	Adding new participants in the AMS MDT.	Positive impact of having a full MDT.
		Building trust between the MDT team members.	Having a voice in the MDT.	Better understanding between different departments and professionals.	
		Personal growth and building confidence.	Building confidence to ask questions.		
	Quotes	*As we went through the entire study, the teamwork and just what everyone shared was incredible. Absolutely incredible. It didn't even feel like you were working with different healthcare professionals. Because it all just felt like in a way like a family in a way.*	*The biggest thing was to see how excited my team got when they start to get involved and start also to raise their voice..., it forever feels like nurses don't have a voice. Here, suddenly when we started the study, suddenly I get my nurses asking the doctors questions... So that really was a wow for me.*	*From their point of view, I think the relationship strengthened with the pharmacist. 'Cause the pharmacist started doing rounds, which is obviously part of the study, coming in and looking at the doses and checking it. I think there have been, like the golden hour, getting that antibiotic in within that golden hour.*	*I find this process having given us the opportunity to strengthen what we had been struggling with, strengthening that opportunity of the teamwork where everybody's role now has been shown how important it is for the team.*
What were the challenges of working as a neonatal MDT?	Themes	Finding time to meet in person alongside other activities.	Busy schedules of different professionals.	Difficult to meet in person due to different priorities.	Difficulty of involving all the different professionals regularly.
		Sustaining meetings with the MDT.	Sustaining efforts in low-resource	Experience levels of some of the MDT.	Too few resources to be

Continued

Table 3. *Continued*

Questions and resulting themes and quotes		Pharmacists ($n=14$)	Nurses ($n=8$)	Neonatal clinicians ($n=5$)	Clinical microbiologists ($n=11$)
			environment with staff turnover.		able to service the MDT in all hospitals in person.
	Quotes	*The biggest challenge for us was trying to get everybody together for a meeting.*	*I think our biggest challenge is actually the nursing staff. There are very few. So you almost have to continuously teach the same thing almost every week because you're having new faces. That's where we have challenges.*	*We have different doctors; we have three or four paediatricians that come into the unit at different times. And you may find that the microbiologist or even a pharmacist would have to be available from 8 a.m. until half past 12, just waiting for a round to be done.*	*We have a total of one, two, three, four, five, six microbiologists in private practice (for the province). So you can understand the challenge. Where do we have the time to go and do ward rounds with the different neonatal units though?*
What opportunities do you see for neonatal AMS going forward?	Themes	Extend AMS to other wards.	Formalize and standardize AMS so it can be extended to other hospitals.	Extend this work to non-central/ non-specialized hospitals.	Tackle "tick-box AMS"—i.e. hospitals that focus on only having AMS structures in place to comply to audits but have no stewardship programs as such.
		Train more pharmacists to ensure sustainability.	Incorporate Infection Control and Link nurses more.	Strengthen management support.	Address the mindset of doctors.
		More multihospital programmes.	Find opportunities for more nurse involvement.	Identify priorities for improvement and work on it together as an MDT.	Make AMS more accessible to all health professionals not just AMS experts.
	Quotes	*I also wanted to learn more, and I wanted to implement AMS in the rest of the hospital. So as it gave us a very good kickstart to get the AMS programme running, not only in NICU but also in other departments as well. So what we've learnt from the NICU study we have been able to take it further into another ward.*	*I'd want to be more involved, but I don't know how more involved I could be in my capacity as a nurse because I can't prescribe and things like that. But I would want to be involved more just to be able to, I don't know, maybe just know more for now.*	*Smaller hospitals out on the periphery that don't actually have even evidence-based protocols and babies are started on antibiotics that should be included. And even in terms of support… AMS is very last on the list. Sorry. We can't give you a pharmacist forward rounds this month because we're short of staff. I think a lot of this has to be driven at management level to show the importance of stewardship.*	*I think we do need to de-ownership it (AMS). I don't know if that's the right word. But we need to remove that, you know, this is my thing, and I was here for however many years working on it. We should be welcoming people to say, "Come and bring your perspectives". Because we know from years of trying to do this, we can't do it on our own. We need everyone to be recruited in partnership.*

In our study, structural organization, MDT collaboration and changes in unit culture were key drivers in facilitating change. The relationships between professional groups—fostering trust, establishing a shared purpose, improving communication, and enhancing knowledge—had a significant impact on the effectiveness of the NeoAMS intervention. Familiarity among team members was critical to successful collaboration. As a result, communication barriers were overcome and collaboration with

Table 4. Summary of recommendations for the implementation of neonatal AMS in LMICs based on the findings from the NeoAMS study across 14 public and private hospitals in South Africa

Key drivers to facilitate change	Determinants
Awareness and motivation to contribute	Call to action for establishing an MDT for neonatal AMS. Share antibiotic usage and AMR data that may be available as well as case studies that illustrate the need for AMS and/or examples of work done in other neonatal units. Outline learning opportunities, benefits of working in MDTs and opportunity to contribute to neonatal AMS and improve quality of neonatal care.
Time and resources	Identify and formalize a bespoke neonatal AMS MDT. Identify and agree on a limited number of focused interventions. Agree on dedicated pharmacist NeoAMS time, e.g. 1 hour per day. Use a standardized (preferably electronic) data collection tool with minimum essential data needed for tracking progress and outcomes. Set clear timelines and deliverables for MDT members and for each phase of the intervention.
Multidisciplinary interprofessional communication and collaboration	Clarify initial roles of each member of the MDT, encourage the development of these roles over time and document challenges and progress. Build aligned purpose based on roles, vision and goals. Weekly team progress review sessions in-person or virtual. Agree on preferred method for day-to-day MDT communication structures. Include opportunities for feedback and sharing by all members of the MDT.
Knowledge	Neonatal AMS toolkit for pharmacists, nurses and other members of the MDT. Empower MDT members with the knowledge and skills to contribute to AMS interventions, through continuous team-based learning. Provide a platform for teams to learn from each other's experience. Provide access to literature and evidence reviews and include relevant publications in discussions and feedback sessions. Source access to other healthcare professionals experienced in neonatal AMS that can support the team members.
Structures	Use the WHO checklist of essential healthcare facility core elements for AMS programmes in LMICs to audit baseline practices and understand the initial context for neonatal AMS.[a] Implement or update a specific prescription chart for neonatal antibiotics. Integrate Infection Control into the neonatal AMS programme. Involve relevant managers and set up regular feedback structures to share progress and challenges.
Data and information technology	Explore what data are available from different members of the MDT, e.g. Pharmacy antibiotic usage data, Microbiology antibiogram data, hospital data such as length of stay, patient outcomes, e.g. mortality, readmissions etc. In the absence of data, consider other options such as point prevalence studies to establish baseline measures. Agree on outcomes and process measures for focused interventions. Set up a standardized data collection tool to capture essential data to measure intervention outcomes and process elements.

[a]WHO (2019). Antimicrobial stewardship programmes in health-care facilities in low- and middle-income countries: a WHO practical toolkit. p14–16. https://iris.who.int/handle/10665/329404. License: CC BY-NC-SA 3.0 IGO.

pharmacists, particularly in supporting daily rounds and accepting pharmacist antibiotic recommendations, became more apparent. This process involved overcoming the challenges of working as an MDT, gaining a better understanding of neonatal care processes, and advancing improved relationships by being open to listening to all team members.

We believe that a crucial requirement for neonatal AMS is the development and support of MDTs.[33,34] Effective communication within the multidisciplinary collaborative is essential for the smooth execution of any AMS strategies.[33–35] In particular, the communication style and the nature of relationships between stakeholders significantly impact AMS buy-in.[35,36] Effective communication channels that promote dialogue, feedback and shared understanding are critical. Engaging staff at all levels ensures that everyone is informed, aligned and motivated to support the intervention.

Despite barriers, the improved functioning and expanding roles within MDTs were highly rewarding. These advancements facilitated the implementation of common system changes across the 14 hospitals, including policy adjustments (e.g.

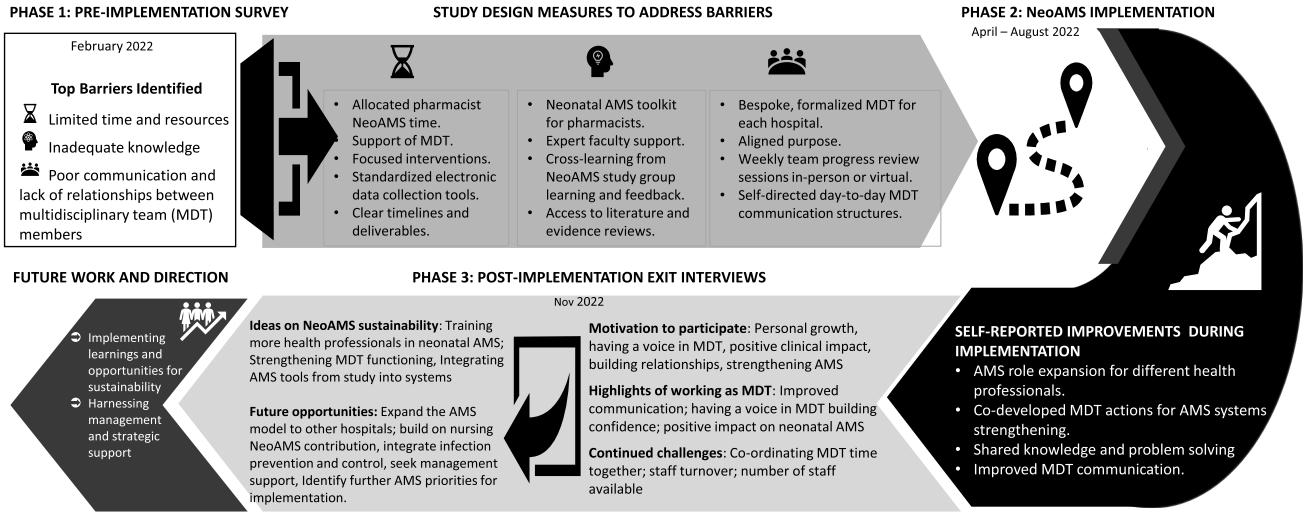

Figure 2. Roadmap of qualitative findings in implementation of neonatal AMS by multidisciplinary neonatal AMS teams across 14 public and private hospitals in South Africa.

antibiotic and diagnostic biomarker protocols), process improvements (e.g. a neonatal AMS-specific antibiotic chart) and strengthened infection control practices. Additionally, these efforts heightened clinician awareness of the importance of AMS.

In a recent systematic review of barriers and facilitators for implementing interventions to improve appropriate antibiotic use in LMICs, Wu *et al.*[37] examined the unique challenges within these settings using the Consolidated Framework for Implementation Research (CFIR). Similar to our study, the most commonly reported factors influencing implementation were found within the inner setting domain, particularly in relation to resource and facility structural constraints. Barriers related to the individual characteristics of target populations, such as reluctance to change prescribing behaviours, were also prevalent. Facilitators included characteristics of the intervention itself, and embedding interventions into routine practice, and process-related factors like stakeholder engagement.

This emphasizes the multifaceted challenges of implementing effective AMS, particularly in neonatal settings, where addressing resource and structural constraints is a critical enabling factor. Our findings also align with a Scottish study, where Currie *et al.*[35] investigated the mechanisms affecting the implementation of a national AMS programme from a multiprofessional standpoint. They identified major barriers related to organizational context and resource availability. Conflicting priorities made it challenging to obtain buy-in from some clinicians, and limited role perceptions resulted in minimal engagement from nurses and pharmacists with their AMS.

The study had limitations. Self-selection bias among professional groups and hospitals could affect the representativeness of the results. The overrepresentation of nurses and underrepresentation of neonatal clinicians from private hospitals in P1, particularly from smaller units (<30 beds), may have skewed the perspectives captured, potentially underrepresenting the views of key stakeholders. The disproportionate multidisciplinary participation in the group exit interviews (P3), particularly neonatal clinicians, raises concerns about the completeness and balance of the data, a limitation previously reported.[22] Additionally, the challenge of navigating group dynamics to ensure that all voices were heard during P3 is a critical factor that could influence the outcomes of these discussions, potentially leading to the dominance of certain viewpoints over others. We did not explore parental perspectives on AMS care provided, nor were the views of infection prevention nurses or executive management included. Without using a theoretical framework, our interpretation of barriers and facilitators might rely more on empirical findings rather than a structured theoretical lens. While we believe the findings are transferable to similar healthcare contexts globally, and our study offers valuable insights, the specific contexts, resource availability and local conditions must be considered when applying the results elsewhere.

A strength of the study is the large number of respondents in each phase, which provided substantial data with 'information power'.[38,39] Qualitative data were collected throughout the NeoAMS intervention using various methods to track the evolving perspectives of AMS MDTs. Furthermore, a frugal and flexible approach was adopted in implementing the AMS intervention across the hospitals, effectively using available resources. This underscores the importance of implementing simple and feasible AMS principles through a team approach. Multidisciplinary alignment on patient outcomes was central to participation. To ensure sustainability, the continuation of MDT neonatal AMS rounds and meetings, increased training for pharmacists in neonatal AMS, and orientation programmes for new staff and interns was proposed.

Conclusions

The study identified that organizational context—particularly staff resources, data access, neonatal care knowledge, competence and unit culture—influences AMS implementation across individual disciplines. The findings emphasize the importance of defined roles within the MDT. The rich data gathered from the implementation process in this study can be used to adopt and scale up this

approach to developing MDTs in neonatal AMS in similar settings, offering opportunities for shared learning from the interdisciplinary model adopted and the lessons learnt in this study.

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Author contributions

All authors made substantial contributions to the following: (i) the conception and design of the study, or acquisition of data, or analysis and interpretation of data; (ii) drafting the article or revising it critically for important intellectual content; and (iii) final approval of the version to be submitted. D.v.d.B. served as Project Manager. A.S.A., M.G., A.M., A.v.J. assisted with data coding. The additional members of MDTs, listed in the NeoAMS Study Group (Table S5) participated in the implementation of the study, provided input and attended the LFSs and attended the group exit interviews.

Supplementary data

Figure S1 and Tables S1 to S5 are available as Supplementary data at *JAC-AMR* Online.

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