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Understanding the complex knowledge economy toward antimicrobial stewardship in West Bengal, India

Ayako Ebata[a,*], Meenakshi Gautham[b], Anne-Sophie Jung[c,1], Mathew Hennessey[d], Sanghita Bhattacharyya[e], Gerald Bloom[f]

[a] Institute of Development Studies, Library Road, Brighton BN1 9RE, United Kingdom
[b] London School of Hygiene and Tropical Medicine (LSHTM), B-140, Ground Floor, Sushant Lok Phase 3, Sector 57, Gurugram 122011, India
[c] School of Politics and International Studies, University of Leeds, Leeds LS2 9JT, United Kingdom
[d] Royal Veterinary College, 4 Royal College Street, London NW1 0TU, United Kingdom
[e] Public Health Foundation of India, House No. 60, 4th Floor, Lane 2, Part of Saidulajab Extension, New Delhi 110030, India
[f] Institute of Development Studies, Library Road, Brighton BN1 9RE, United Kingdom

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ABSTRACT

Knowledge dissemination and awareness raising is a common strategy for fostering antimicrobial stewardship and tackling antimicrobial resistance (AMR). However, empirical evidence suggests that the dissemination of technical/biomedical information about AMR, alone, is insufficient to improve antibiotic use in resource-poor settings. This is because antibiotic users' decisions are based not only on biomedical knowledge but also on social and clinical information that is specific to local healthcare realities, and healthcare providers' clinical knowledge and judgement. In this article, we propose a framework that identifies knowledge critical to deciding a course of antibiotic treatment for possible infection in resource-poor settings, and how to improve the knowledge flow to improve antibiotic use. Specifically, we focus on understanding three domains of knowledge that guide antibiotic users' decisions: 1) scientific evidence, and evidence-based treatment guidelines; 2) local knowledge of infection patterns and risks, and the susceptibility of organisms causing infection to different antibiotics; and 3) personal and social characteristics of the patient. Drawing from the theory of information asymmetry and empirical data from West Bengal, India, we show that all three domains of knowledge demonstrated degrees of asymmetry, and community-level practitioners' knowledge was not effectively taken into account in clinical guidance. We conclude that interventions targeting AMR need to reflect all three knowledge domains to be effective in clinical settings.

1. Introduction

Knowledge dissemination and awareness raising is a common strategy for fostering antimicrobial stewardship and tackling antimicrobial resistance (AMR) (Esmaily et al., 2010; Shrestha et al., 2006; Sun et al., 2015). Interventions proposed by international and national policy makers frequently emphasise the dissemination of clinical evidence concerning AMR and antimicrobial usage guidelines based on such evidence (Fleming Fund, 2022; O'Neill, 2016; WHO, 2015). WHO's AWaRe (Access, Watch, Reserve) categorisation of antibiotics (WHO, 2022) is an example of such effort to disseminate knowledge regarding appropriate antibiotic use to healthcare professionals. These initiatives specifically target the common challenges, particularly in low- and middle-income countries (LMICs), related to the generation and dissemination of information on AMR and appropriate use of antibiotics among healthcare professionals, who make decisions on how to treat common infections (Do et al., 2021). The underlying assumption is that information about growing resistance and guidance on appropriate antibiotic use will catalyse behavioural change. Furthermore, knowledge-driven interventions are often considered less complex than addressing the broad systemic factors, which are time- and resource-intensive, and require coordination among multiple

* Corresponding author.
E-mail addresses: a.ebata@ids.ac.uk (A. Ebata), Meenakshi.Gautham@lshtm.ac.uk (M. Gautham), A.S.Jung@leeds.ac.uk (A.-S. Jung), mphennessey@rvc.ac.uk (M. Hennessey), sanghita2214@gmail.com (S. Bhattacharyya), g.bloom@ids.ac.uk (G. Bloom).
[1] While conducting the work for this manuscript, Dr. Jung worked at: London School of Hygiene and Tropical Medicine (LSHTM), Keppel St, London WC1E 7HT, United Kingdom

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stakeholders, thus complicating the process of enacting change (WHO, 2018).

However, empirical evidence overwhelmingly supports that the dissemination of technical information about AMR, alone, is insufficient to improve antibiotic use (Radyowijati and Haak, 2003; Wilkinson et al., 2019). This is because antibiotic users' and prescribers' decisions are influenced by not only scientific evidence and guidelines but also other kinds of information (Tompson and Chandler, 2021). These include prescribers' knowledge about patients' and livestock keepers' concerns related to poverty and livelihoods, people's experience and knowledge of access to high-quality healthcare, and the contexts with limited water, sanitation and hygiene (WASH) in people's residence and livestock production systems (Araya et al., 2016; Collignon et al., 2018; Hinchliffe et al., 2018). All these dynamics lead to scenarios, particularly in resource-poor settings, where untreated infections may become life-threatening (Pokharel et al., 2024). Consequently, prescribers may resort to what is termed "irrational" antibiotic use from a clinical perspective, although this may be rational when viewed through a social or economic lens (Hinchliffe et al., 2018; Tompson and Chandler, 2021). This highlights the necessity of integrating both biomedical knowledge and social and clinical information at the community level in shaping the decisions to use antibiotics in clinical settings.

In this article, we propose a framework that identifies the knowledge critical to deciding a course of treatment for possible infection in resource-poor settings, and how to improve knowledge flow to improve antibiotic use. Specifically, we focus on understanding *information asymmetry* (Akerlof, 1978) in three domains of knowledge that guide antibiotic users' decisions: 1) scientific evidence, and evidence-based treatment guidelines; 2) local knowledge of infection patterns and risks, and the susceptibility of organisms causing infection to different antibiotics; and 3) personal and social characteristics of the patient. Substantial barriers to access knowledge on AMR and appropriate antibiotic use in LMICs (Otaigbe and Elikwu, 2023) leads to *information asymmetry* where some actors have better access to scientific evidence and guidelines than others. This is particularly problematic for highly marketized healthcare settings with limited regulations and third-party monitoring in LMICs (Bloom et al., 2008). Information asymmetry leads to a poor understanding of risks (Arrow, 1963), which in turn prevents individuals, communities and organisations from making informed decisions (Coveney et al., 2023; Tulio et al., 2023). Moreover, those who control knowledge – e.g. pharmaceutical companies – may exploit their knowledge to pursue specific, often economic, objectives (Lexchin, 2021; Thawani and Gharpure, 2009).

Therefore, our research addresses the following three questions:

1. How are different kinds of knowledge asymmetrically distributed along the antibiotic supply chains? How are they disseminated?;
2. What socio-political and economic interests influence asymmetries in knowledge dissemination and acquisition?; and
3. What can be done to improve the use of antibiotics in a pluralistic knowledge economy of antibiotic supply chains?

We focus particularly on informal providers (IPs) of human healthcare, who are vital sources of primary healthcare for marginalised people in many LMICs (Christian et al., 2023; Godman et al., 2020; Kisangala et al., 2023; Matin et al., 2020). While we focus on the human health sector, our data were generated from a One Health project, involving both human and livestock antibiotic supply chains.

2. Methods of data collection and analysis

2.1. Study approach

As the aim of this study required an in-depth exploration of how the three knowledge domains in our framework are distributed asymmetrically, and how and what power relationships between different stakeholder groups influence the extent to which knowledge is disseminated or withheld, we followed a qualitative research design. We conducted qualitative interviews with key stakeholders along antibiotic supply chains for human use (Table 1) – from manufacturing, distribution, sales and use – between September 2019 and January 2020. This research was conducted as a part of a larger project, aiming to foster antimicrobial stewardship for both human and veterinary sectors. While this article focuses on antibiotic prescribing, community-level perspectives on antibiotic use is analysed in a separate article (Gautham et al., 2024).

2.2. Study sites

We selected West Bengal, the fourth most populated state in India with 91 million inhabitants (Government of India, 2011). The state reported a high burden of infectious diseases (IIPS, 2013) and most (84 %) of its 7 million residents live in rural areas (Government of India, 2011). Also, studies conducted in the state revealed poor knowledge and inappropriate antibiotic use practices by healthcare professionals – in both formal and informal sectors – (Das et al., 2016; Gautham et al., 2021; Gautham et al., 2022; Nair et al., 2019a) as well as multi-drug resistance bacteria in the environment (Pal et al., 2020). These characteristics make West Bengal an important site to understand the rural healthcare realities and how the burden of infectious diseases influences antibiotic use.

We conducted this research in South 24 Parganas district, the largest and the second most populated district in West Bengal (Government of India, 2011). Within this district, we selected two Gram Panchayats – village administrative units – purposively based on their remoteness and access to healthcare facilities. Site 1 was located at approximately 60 km from Kolkata, the state capital, and had relatively good access to various healthcare facilities: several pharmacies and private clinics could be found within 10–20 km as well as a block local government Primary Health Centre (PHC) approximately 10 km away and another less-resourced PHC closer to Site 1. Site 2, in contrast, was significantly more remote at approximately 95 km from Kolkata, where a ferry is required to reach the road leading to the state capital. In Site 2, only one PHC was identified alongside another non-profit healthcare facility with two doctors.

The selected study sites were predominantly rural, and healthcare provision for both people and animals largely relied on IPs due to the remoteness and inaccessibility to formal healthcare settings. In our previous studies (Gautham et al., 2021; Hennessey et al., 2023), we identified an active body of IPs in both Sites (19 in Site 1 and 21 in Site 2). Also, antibiotics used in our study sites were produced by both foreign and domestic pharmaceutical companies (Hennessey et al., 2023), and supplied by these companies' medical representatives through wholesale stockists, local pharmacies or drug shops, and healthcare providers (both formal and informal).

2.3. Study participants

In total, we conducted 23 qualitative interviews across the two study sites (Table 1). As our focus was IPs' practices as a critical source of

Table 1
The number of study participants.

Stakeholder groups	Site 1	Site 2	Total
Formal doctors	2	3	5
Informal providers	3	4	7
IP association representative	1	1	2
Pharmaceutical representatives	3	1	4
Pharmacists	1	0	1
Medicine stockists	1	0	1
Medicine wholesalers	0	2	2
NGO	0	1	1

primary healthcare for rural residents in the study sites, we interviewed three and four IPs in Site 1 and 2, respectively, and one representative from IP associations in each of the study sites. Also, as our previous study indicated that IPs' relationship with formal doctors as well as pharmaceutical representatives – i.e. sales representatives from pharmaceutical companies – critically influence IPs' antibiotic knowledge and usage practices (Gautham et al., 2021), we interviewed these stakeholders as well. In addition, we interviewed one pharmacist, medicine stockists, medicine wholesalers, and an NGO. Some of these stakeholders were relevant in only one of the study sites because they did not operate across both study sites.

While we recognise that the sample size is small, our purpose is not to generate representative evidence across a large population. Rather, this approach allows us to explore IPs' practices and different kinds of knowledge by multiple stakeholder groups in depth.

2.4. Study instruments and data collection

We used semi-structured qualitative interview guides for all interviews. The interviews addressed questions on knowledge about antibiotics, their antibiotic usage practices and rationales behind them, their understandings and perceptions of AMR, its causes in their clinical and/or business settings, relationships with other stakeholders along antibiotic supply chains (specifically with IPs), and possible interventions and ways to address AMR.

Interviews were conducted by a team of three to four researchers – one or two junior researchers trained in qualitative research and two senior researchers. We conducted interviews in either English or Bangla, depending on the respondents' language preference. Interviews were recorded, transcribed, and translated to English in the case of those conducted in Bangla by local researchers. A senior researcher proficient in Bangla checked the accuracy of transcripts.

2.5. Data analysis

Two authors coded the first two interview transcripts in English, and one coded the remaining transcripts. We employed the content analysis method (Drisko and Maschi, 2016), which is a research technique that draws inferences from empirical data to a specific context to, for example, understand views and interests of individuals and stakeholder groups (Krippendorff, 2018). For our research, the "context" refers to rural healthcare settings in resource-poor communities, and we extracted information according to the three kinds of knowledge in our framework, and how they interact with the relationships between actors as well as individual actors' roles with respect to antibiotic use, using NVivo (V.12). The codes linked to relationships and antibiotic use practices (especially by IPs) formed the backbone of our analysis as they articulate what knowledge IPs draw on in making clinical decisions, and who and what social, political and economic dynamics influence the three knowledge domains and individual practices linked to healthcare and antibiotic use. We also coded on informal arrangements – e.g. between IPs and formal doctors or pharmaceutical representatives – as well as mechanisms (or lack thereof) to ensure the quality of practices. In this paper, we present direct quotes from these interviews, which are anonymised.

2.6. Ethics

We obtained ethics approval for this research from the London School of Hygiene and Tropical Medicines (LSHTM) Ethics Committee (LSHTM Ethics Ref: 17484) and the Institutional Ethics Committee of the Indian Institute of Liver and Digestive Sciences, West Bengal (No. IILDS/IECHR/01/2019). We also obtained informed consent signed by interviewees to participate in this study.

3. Framework to understand critical knowledge for antimicrobial stewardship

We now present our framework in Fig. 1, which links three domains of knowledge that healthcare professionals – both formal and informal – rely on in making clinical decisions: 1) scientific evidence, and treatment guidelines – e.g., dynamics of AMR, appropriate use of antibiotics; 2) local knowledge of the organisms likely to cause infection – i.e., local infection patterns which may or may not be guided by diagnostic testing; and 3) local understandings of appropriate use of antibiotics and medicines more broadly – e.g., social norms about "good" practices, and people's financial and social ability to access best quality healthcare.

Fig. 1 first situates the medicines, i.e., antibiotics, at the core in Fig. 1. Scientific evidence and treatment guidelines provide healthcare providers information on biomedical mechanisms to treat infection and for antibiotics to become resistant, and thereby informs how antibiotics need to be used in clinical setting. This knowledge domain becomes embedded in the second domain, i.e., local knowledge on infections and treatment. This is where scientific evidence becomes integrated in a particular clinical setting characterised with (in)access to diagnostic tools, empirically feasible methods to link infection patterns to causes, which helps determine disease perceptions about causality and severity. Finally, personal and social characteristics of patients shape how providers dispense or prescribe antibiotics to a specific individual in a given setting. This domain considers the patients' and users' economic and social contexts and available healthcare facilities and their capacity, thereby informing contextually appropriate and relevant patterns of antimicrobial use.

Across LMICs, scientific evidence to guide everyday clinical decision making – i.e. the second knowledge domain – is often limited because surveillance of resistant organisms and rapid diagnostic tools are unavailable in a timely manner (Gandra et al., 2020; Iskandar et al., 2021; Okolie et al., 2023). This means that the available treatment guidelines may not represent the local patterns of antibiotic resistance and people need to draw on other sources of information to decide on the appropriate antibiotics to use for a given condition at a given time (Kalam et al., 2021; McKinn et al., 2021). Patients value IPs, who are able to give them drugs that they perceive as "value for money" since they help them recover from illness quickly and cheaply. IPs and other community-based practitioners are aware of the local disease dynamics and broader hygiene conditions. As a result, their advice is specific to the context and the patients, and aligned with our third knowledge domain.

Denyer Willis and Chandler (2019) argue that systemic issues – such as persistent poverty, weak health systems and precarious livelihoods – encourage people to use antibiotics as a "quick fix" to counter these issues. In other words, judgement regarding expertise does not solely depend on scientific evidence but also on empirical and locally embedded knowledge about the local disease and infection dynamics, socio-economic status of patients and livestock keepers. It also depends on the tacit knowledge that allows antibiotic users to respond to wider structural constraints in health systems. In this regard, international good practice guidelines may not be suited to treat specific illness and conditions locally. For instance, prescribers use "watch" category antibiotics according to the WHO guideline (Sharland et al., 2022) instead of "access" because they are less expensive in a particular local context (Gautham et al., 2022). Also, when referral to specialised care is poor and common infections can be fatal, people are incentivised to take antibiotics as preventive measure (Otaigbe and Elikwu, 2023). This highlights the need to understand antibiotic prescribing from the perspectives of the communities (Gautham et al., 2024; Mitchell et al., 2022).

In addition, all three domains of knowledge and information are asymmetrically distributed along the antibiotic supply chains due to people's social and economic standings. Information asymmetry might arise naturally – because of particular stakeholders' roles and geographical locations. Equally, however, each type of supply chain

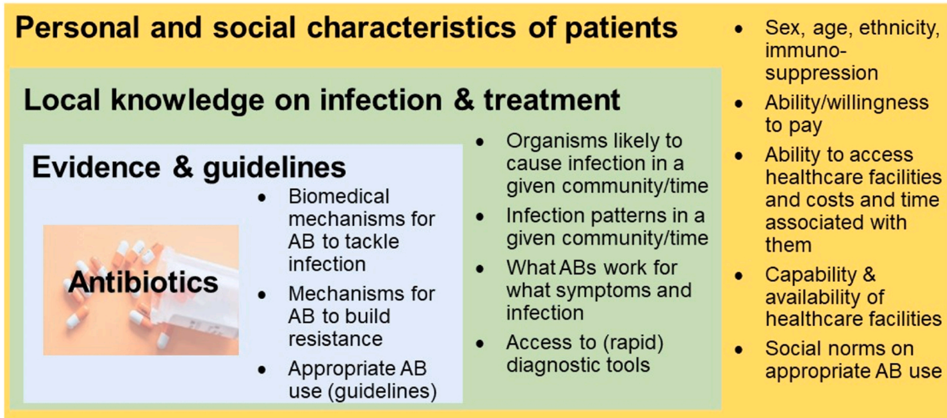

Fig. 1. An epistemic framework of knowledge domains that guide antibiotic use in community settings.

stakeholder may use information asymmetry to achieve their socio-economic objectives (Steinle et al., 2014). Often, their objective is profit driven such as to increase and maintain clients and livelihood opportunities (Wilkinson et al., 2019). Empirical evidence suggests that many focus on doing so in a socially desirable manner and maintain business relationships by winning the trust of patients and/or farmers (Barker et al., 2017). Also, information asymmetry reflects the biases, visions and ideologies of powerful actors who can shape the narratives (Amábile-Cuevas, 2022; Sumberg et al., 2013). In such complex knowledge economy, antibiotic users therefore need to navigate whose knowledge is most trustworthy and relevant to determine appropriate use of antibiotics.

4. Results

4.1. Knowledge 1: evidence and guidelines

In relation to biomedical knowledge about antibiotics, our interviews suggested that scientific evidence was possessed mainly by formal sector actors – i.e., formal doctors, formally educated and trained pharmacists, pharmaceutical company representatives, and government officials with appropriate training. In contrast, this knowledge was inaccessible to IPs. Though most respondents recognised that IPs were the most important source of primary healthcare for India's rural populations and commonly dispensed antibiotics, there were no efforts by the formal health sector or other government departments to systematically train them until 2018 when a general training programme was initiated (although this may not have addressed responsible antibiotic use) (Gautham et al., 2014). IPs have been historically denied access to evidence-informed training as explained by an IP association representative:

> "Initially, we used to fight for our rights to get trainings as we are doing this practice and we also know that many of us has no formal knowledge or training… But the government did not respond to us till 2018." (IP association_1_NP)

This was largely due to the perception by the formal medical stakeholders that IPs' practices were poor quality and dangerous:

> "So what is he (IP) doing with patient with a tumour? He made him (patient) lie down on a bed near a road and cut the tumour." (Pharmaceutical representative_2_NP)

A formal doctor expressed concern that there is no mechanism to control and monitor the quality of care by IPs:

> "RMPs (Rural Medical Representatives, or IPs) don't have… any official body which can tell them, 'If you don't stop this malpractice, I am going to stop your practice'" (Formal doctor_2_RB)

Another concern by the formal sector was the competition between formal and informal providers, and discrediting the formal education and accreditation process if IPs were recognised by the government:

> "They [the government] are encouraging them [IPs]. In fact, if some of them [IPs] did some [training] courses, then what is the use of an MBBS doctor? MBBS is examination, which is the toughest examination!" (Formal doctor_3_NP)

As a result, evidence-based information and clinical guidelines were not systematically passed onto IPs from those who possessed this type of knowledge. The government – both state and national – would be in a position to endorse and facilitate training of IPs. However, the programme offered by them was sporadic and also limited in scale, and most strikingly the content of the training was perceived to be too basic:

> "They (the government) inform us about various government programme, health policies and make us aware… The training is not worth anything." (Informal provider_3_NP)

As a result, IPs turned to non-governmental organisation (NGO) and formal practitioners – i.e., trained medical doctors – for more complex biomedical and clinical knowledge that could be used for everyday practices:

> "And for doing practical, I went to many places with a doctor from a local hospital." (Informal provider_1_RB)

The paradox is that, while formal sector denies IPs legitimacy and access to biomedical knowledge through formal channels, the very same actors are providing medical training on an informal basis. Working with IPs benefited formal practitioners as it could reduce the healthcare burden on the formal sector and IPs would refer patients to them:

> "Definitely they [IPs] refer the patients to us. Every day they refer some patients." (Formal doctor_3_NP)

Another important source of biomedical knowledge for IPs was pharmaceutical companies who hold "campaigns" and "training sessions for IPs":

> "4–5 campaigns in one year are held. There may be a programme arranged with 50 doctors (IPs) on topics such as diabetes. Sometimes the hospital (organises them), sometimes it is held by a medicine company." (Informal provider_1_RB)

The training provided by pharmaceutical companies had more practical information than government trainings, yet was largely based on their perceptions of IPs' expertise and knowledge, and commercial interests. Because pharmaceutical representatives perceived that IPs, unlike formal doctors, did not have enough scientific knowledge to understand the complex biomedical information required to prescribe antibiotics appropriately, they shared only a limited aspect of biomedical knowledge linked to antibiotic use:

> "They (IPs) don't know which medicine works on which disease. What we say [to IPs], they will treat accordingly. Because they know about the medicine that they had seen been written [by formal doctors]. But they don't know about the latest molecules." (Pharmaceutical representative_2_NP)

In other words, pharmaceutical representatives and companies generated asymmetry in the biomedical information shared with formal and informal healthcare providers. Similarly, the flow of biomedical information from pharmaceutical companies to stockists and pharmaceutical shop keepers was limited. This was largely because medical representatives regarded stockists and shop keepers' role to have their medicines available at the shop for healthcare providers – whether formal or informal – and therefore they did not require any biomedical information to dispense the medicines. Considering that pharmacists are also influential stakeholders for IPs' practice (Gautham et al., 2024), this contributed to further information asymmetry between IPs and biomedical professionals and pharmaceutical representatives.

4.2. Knowledge 2: local knowledge on infection and treatment

Regarding the second knowledge – i.e., local knowledge on infection and treatment –, the overall context where IPs played an important role as a healthcare practitioner was characterised with limited public sector capacity to provide rural residents with timely and high-quality care. Public hospitals were often far away from rural communities, and doctors there were overwhelmed with the demand for healthcare:

> "In a rural area's government hospital, even in a super specialty hospital, doctors start seeing patients from 10 am to 2 pm. In 4–5 hours doctor has seen 180–200 patients. So each patient gets less than 30 seconds" (Formal doctor_2_RB)

Given the constraints in the public sector, IPs were a critical first point of contact for rural populations. They resided in the same community as patients, which made them more accessible to people than faraway public hospitals:

> "As we live in remote areas where doctor is not available on call, we [IPs] provide the primary support and refer to hospital…. As you are living in a village, and are practicing rural, people will run to you at 'raat-birat' [night or any inconvenient time]. You should see immediately what the situation is, provide whatever primary support is needed and send him [patient] to a place he needs to be sent." (IP association_1_RB)

Unlike formal doctors, IPs also visited patients in their own homes, which was critical for less mobile people (e.g. carers for small children, elderly people).

Poor health systems setting also meant that (rapid) diagnostic testing for sources of infection was rarely available in the rural contexts we studied. This limited information about the biomedical causes of the illness of concern for both formal and informal practitioners, and therefore made them both equally uncertain about whether and what antibiotics were needed to relieve a particular condition:

> "…in civilised countries if any person has infection, they send sample to lab for culture sensitivity test to know whether it is bacterial infection or fungal, microorganism, and strain of that and antibiotics spectrum. Show me one lab in this area who can do this." (Formal doctor_2_RB)

In addition to laboratory diagnostics being unavailable, formal providers noted that even the available diagnostic tests may not be reliable:

> "There are lots of (diagnostic) laboratories, but what is going on there? I have no idea. The quality of these (diagnostic) services is going down." (Formal doctor_3_NP)

In the absence of reliable diagnostic testing, actors who possessed evidence-based information and treatment guidelines – i.e., formal doctors and pharmaceutical representatives – cited structural factors such as persistent poverty and lack of general hygiene as potential causes of infection in the communities. As a result, many households kept antibiotics at hand:

> "People commonly keep medicines [not just AB] because of poverty and poor infrastructure… If you do a survey among the households of in this area, you'll find almost every household keeps medicines in their home." (Formal doctor_2_RB)

Given limited availability of high-quality diagnostic testing and poor general hygiene in the communities, both formal and informal practitioners decided on treatment course based on available evidence-based knowledge, their observation and prior experiences. Besides their clinical knowledge acquired from their formal education, formal healthcare professionals, at times, also referred to national and international guidelines in identifying appropriate courses of treatment:

> "Suppose the patients is not doing well. So I advise [them] to do a lab exam, and then I give some antibiotics… We have some medical knowledge and clinical ideas, we apply that [to prescribe antibiotics without diagnosis]. There are also national guidelines we have, there are AIIMS [All India Institute of Medical Sciences] guidelines. We follow that." (Formal doctor_1_NP)

On the contrary, no IPs we interviewed reported referring to clinical guidelines. They treated a set of common conditions in the community such as fever, cold-like symptoms, diarrhoea, and abdominal pain in people. For these common symptoms, they had "standard diagnostic procedures" that they learned through experiences and working with formal healthcare providers:

> "There are generally 7–8 conditions I treat, like fever, throat pain, diarrhoea, abdominal cramping, cold and cough etc. But if I see a person with fever, and it's not getting better for 4–6 days I generally refer to that patient to XYZ Health Centre… For fever, I give paracetamol. In case of diarrhoea, I give them Norflox TZ. In case of cold and cough, I treat them with Amoxicillin, Mox, amoxicillin potassium calvum. I noticed that the formal doctors also give their patients same medicines. In case of cough, I give them Ascoryl syrup." (Informal provider_4_RB)

They matched symptoms for their medical assessments and diagnosis and for decision making about drugs. When they judged that they were unable to handle a condition, IPs referred them to formal healthcare facilities (e.g., hospitals) as demonstrated in the quote above. Another strategy for IPs was to consult formal practitioners on the phone:

> "When I get tough or problematic cases, I call them [formal doctors] over the phone. I call Dr. X (a qualified medical doctor). There are others there. Dr. Y. Them and other doctors. One of my in-laws is a doctor. I even take his advice." (Informal provider_2_RB)

Because IPs were denied access to evidence-based information and guidelines, they drew advice from multiple sources of information – i.e. formal healthcare professionals, pharmaceutical companies, their own experiences, and even those who might not be qualified. This enabled them to treat conditions that they were not entirely experienced with, which could lead to providing inappropriate care for a given condition including encouraging inappropriate use of antibiotics. The influence of pharmaceutical companies added to this complexity where the advice IPs drew from them was commercially motivated for the companies. Therefore, the lack of systematic access to scientific evidence and guidelines led to healthcare professionals – both formal and informal –

making decisions based on various sources of information, some of which have individual and commercial conflicts of interests.

4.3. *Knowledge 3: personal and social characteristics of patients*

Antibiotic use was highly influenced by social norms about its appropriate use in a given biomedical and health systems context. As described above, rural practitioners, both formal and informal, were acutely aware of the challenges people faced with regards to healthcare access in rural areas. As a result, their practices were based on a good understanding of the social context where IPs were expected by patients and clients to prescribe antibiotics. People in the study sites were generally poor and often lacked access to sanitary infrastructure. Minor illness, especially in children, could pose a significant threat to their health and adult illness had implications for household finance due to lost wages from precarious work – a context articulated by Denyer Willis and Chandler (2019) – or catastrophic health expenditure from worsened infection (Eze et al., 2022). This meant that sickness needed to be cured quickly, and antibiotics played an important role:

> "Now suppose in our village, it may happen that a patient comes today and it would be good to be cured tomorrow because they may be daily labourers. For that reason, I may give analgesic for one or two days. If not cured, then antibiotics have to be given." (Informal provider_1_RB)

IPs balanced the needs and expectations from patients with their own livelihoods. Pharmaceutical representatives were aware of this, and therefore their training on what antibiotics to prescribe when, was of practical importance to IPs:

> "…one doctor [IP] has to consider a lot of things while he is checking the patient. 'I have to take money from the patient, I have to sell the medicine, I have to make payments to the distributor plus I have to cure so that my patient profile gets better.' So many things the doctor [IP] has to consider. What they look for truly is the price… and short dosage for patient recovery." (Pharmaceutical representative_1_RB)

> "When (medical) representatives come, I get information about new antibiotics. When I use their company's medicine, they [companies] explain about antibiotics." (Informal provider_1_RB)

However, our interviews also revealed that IPs were aware that they needed to be cautious while prescribing antibiotics. For instance, for common conditions such as fever and cold, one IP claimed that he did not prescribe antibiotics at the first instance as his mentor had asked him not to. When he did because conditions did not improve, he would recommended the patient to complete a full course and/or he would refer such patients to formal healthcare facilities:

> "For fever and cold, and dehydration, we start with plain medicine. But then, after giving 3 days of paracetamol for fever, they would often come back. Then we need to think of alternatives, but we do not give antibiotics on the first visit. Our doctor sir says, "If you give antibiotic, tell the patient to complete the course." … Then, I will give amoxicillin or ofloxacin and observe. If it still persists, we tell them to go elsewhere or ask them to do the blood test." (Informal provider_1_NP)

In the case of illness in children, some IPs preferred to refer directly to specialists:

> "With small children, I do not take the risk and recommend immediately to the child specialist; either a DCH doctor or to the hospital." (Informal provider_2_NP)

People expected IPs to be more affordable than formal providers. There was a sense that IPs' role is to cure sickness quickly and cheaply, and people were unwilling to pay similar fee to IPs than formal providers:

> "As we practice in the countryside, we have to be mindful of the economics first – be it in relation to antibiotics or something else. When people go see a big [formal] doctor, understandably, they have 200–500 rupees in their pockets. When they come here, they will bring less money with them." (Informal provider_1_NP)

Given this expectation, IPs charged fees based on their understanding of the patients' and clients' socio-economic positions. IPs regarded themselves as a community member, who were providing socially meaningful services through this enterprise:

> "I do not see my work as business. It's more about securing our livelihood through social service for common people." (Informal provider_1_NP)

Also, being in the same community as patients, IPs were held accountable informally and socially. This made them sensitive to people's needs and therefore respond to their demands, which helped them retain a group of loyal patients.

Therefore, IPs' decisions regarding antibiotic use were significantly influenced by information about patients' willingness and ability to pay to provide the care that they expected from IPs. For instance, IPs often provided care on loans:

> "They [patients] don't pay me immediately. We have halkhata [Bengali year ending ceremony][2] also. They pay me according to their convenience…If a patient needs 200 rupees medicine, I take 100 rupees from them. I buy medicines according to the immediate need and affordability of the patient." (Informal provider_4_RB)

Also, prescription of antibiotics was influenced by the notion that, if they did not provide antibiotics, other IPs would:

> "If I I'm well aware of antibiotic resistance and stopped using it, the patient will move on to another practitioner and for sure he will give him an antibiotic." (IP association_1_NP)

Because many IPs operate in an area, they needed to differentiate themselves from their peers based on relationships with patients and clients. Therefore, IPs effectively utilised their understandings about patients' characteristics to compete against other IPs as well as other types of healthcare providers and maintain livelihoods.

5. Discussion

We set out to explore knowledge asymmetries and their drivers across three knowledge domains. Our empirical data suggest that all three domains of knowledge – evidence and guidelines; local knowledge on infection and treatment; and personal and social characteristics of patients – demonstrated degrees of information asymmetry. IPs were disadvantaged with respect to biomedical knowledge but advantaged with respect to knowledge about patients. A comparison of knowledge asymmetries across these three knowledge domains is shown in Table 2.

Our analysis shows that powerful actors – pharmaceutical companies, formal doctors and the government – demonstrated a tight control over biomedical knowledge and clinical guidelines based on it. Biomedical knowledge differentiated them from IPs, and gave them social status as well as the opportunity to take advantage of IPs. For instance, IPs would refer patients to formal practitioners if a case was judged too complex for them to deal with. Therefore, this helped formal practitioners to have a group of IPs who brought them more income-generating opportunities. For pharmaceutical companies, IPs are an important gateway to the vast rural markets where patients were looking for a quick remedy for common infection (Gautham et al., 2021). Therefore, these powerful actors resisted sharing scientific knowledge to

[2] Interviewees reported that lenders can be approached at the end of Bengali year to pay back fully or partially what they owe.

Table 2
Access to all three sets of knowledge that guide AMU per different stakeholders.

Knowledge guiding AMU	Knowledge access per stakeholder			Implications for anti-microbial stewardship
	Informal providers (IPs)	Formal doctors	Pharmaceutical companies	
Evidence & guidelines	Poor access	Good access	Good access	• Poor and non-standardised quality of care by IPs; • Evidence distorted by financial & personal interests (e.g. by pharmaceutical companies);
Local knowledge on infection & treatment	Moderate access	Moderate access	Moderate access	
Personal & social characteristics of patients	Good access	Poor access	Poor access	• Personal and social realities of healthcare not reflected in guidelines; • Scientific advice remains irrelevant & impractical
⇨ Knowledge flow required to improve antibiotic use and antimicrobial stewardship				

IPs in a systematic manner.

The motives and process in which powerful actors control knowledge is well documented in the literature on power (Gaventa and Cornwall, 2008; Jolly et al., 2009; Newell, 2014; Weiss, 2016). Technical knowledge – e.g. scientific evidence – may be seen simply as a "resource" for individuals to make decisions (Sending, 2003) – for instance, regarding the appropriate use of antibiotics in a purely technical term. However, those with power can intentionally generate and control knowledge to set particular agendas and/or encourage behaviours by others that suit their interests (Bachrach and Baratz, 1970; Glover, 2010), as we witnessed in our study scenario.

From an antimicrobial stewardship perspective, the asymmetry in scientific information and local understandings of infection mechanisms is problematic because 1) the advice given to IPs on antibiotic use is influenced by (often economic) interests of the advisor – as in the case of pharmaceutical representatives – and 2) IPs do not have sufficient biomedical information to improve their antibiotic use. For instance, pharmaceutical representatives, from whom IPs obtained information about antibiotics, perceived that certain information was too complex for IPs to understand. Therefore, company-organised trainings were generally limited to conveying simpler messages about products and their use, and misaligned from public health goals. For companies, this was sufficient to serve their purpose: i.e., to inform IPs about their products and promote their usage in rural settings. Because IPs did not have adequate access to biomedical information and guidelines, they were vulnerable to being misled by such piecemeal trainings, leading to non-standardised practices by IPs. Also, available guidelines might embody a western bias in clinical trials, which may not reflect the local reality of infection and AMR. As a result, both IPs and formal doctors make decisions based on their empirical and clinical experiences, a finding reported by other researchers as well (Nair et al., 2019b).

The only set of knowledge that IPs demonstrate advantage over others was related to their understanding of personal and social characteristics of patients. This knowledge domain is constructed by a combination of context, IPs' practices, and IPs' perceptions of their patients' expectations about "best practices". Social norms about "best practices" about antibiotic use are constructed by rural communities based on a combination of biomedical and health systems realities – i.e. poor sanitation infrastructure, weak health systems, and uncertainty regarding the biomedical cause of illness –, economic pressure to minimise the cost of healthcare, and their experiences of using antibiotics (and other medicines). These factors formed the context in which IPs operate and utilise antibiotics. Indirectly, pharmaceutical companies' marketing to promote antibiotics may have contributed to shaping the opinions of community members and thereby influencing the "norms" about antibiotic usage. This is what Lukes (2005) refers to as "the third face of power" – or the "constitutive power by Dallas et al. (2019) – that powerful actors use narratives and discourses to influence public opinions and create norms.

However, this domain of knowledge is rarely taken into account in identifying solutions to tackle AMR and design clinical guidelines. Powerful actors can frame AMR and its solutions by determining whose perspectives are important while others are not (Gaventa, 2006). In our study context in rural West Bengal, formal doctors and the government did not perceive information about patients' personal and social circumstances as "legitimate" in informing clinical practices, and therefore failed to consider them in developing locally relevant antibiotic usage guidelines. Similarly, international and national guidelines have failed to consider how IPs and rural communities manage infectious diseases with limited availability and affordability of formal health systems (Broom et al., 2014). Guidelines that do not reflect local realities are impractical, and therefore likely to lead to limited adoption by community-based practitioners and community members. Community engagement for AMR (Mitchell et al., 2022) is a critical process to facilitate marginalised communities and community-level practitioners to design actions based on their living conditions. Indeed, evidence across agricultural development and animal health shows the effectiveness of designing interventions and technologies through community participation (Catley et al., 2012; Chambers, 2021; Ebata et al., 2020; Fischer and Chenais, 2019). This demonstrates the importance of reflecting local knowledge into strategies to tackle complex challenge such as AMR.

6. Conclusions and policy implications

In this article, we have proposed a framework to understand relevant knowledge that guides ground-level decisions regarding antibiotic use. Based on this framework and its empirical application in West Bengal, we argue that all three domains of knowledge – evidence and guidelines; local knowledge on infection and treatment; and personal and social characteristics of patients – need to be taken into account in developing effective antimicrobial usage guidelines to tackle AMR (or any other locally relevant clinical guidelines). In large-scale efforts to tackle AMR, the role of scientific evidence and guidelines is regarded as the single most important kind of knowledge. However, as our research demonstrates, consideration of local, socially and personally relevant knowledge often governs people's antibiotic use. In other words, ignoring knowledge about local patterns of infection, the needs of local providers and people's realities will not lead to effective improvement of antibiotic use. Therefore, we contend that good practice guidelines need to reflect all three knowledge domains presented in our framework to be effective.

In doing so, there is an urgent need to recognise the role of IPs as both healthcare providers and informants of healthcare realities especially in rural healthcare settings for both animals and humans. Across LMICs, informal healthcare providers are the only source of medical advice for many marginalised and vulnerable communities. While informal practitioners may be inadequately trained, our evidence shows that this is due to the power relationships that actively create information asymmetry particularly with respect to scientific knowledge and guidance. This leads to IPs being denied access to biomedical knowledge, leading to their poor understanding of infection patterns and treatment, and blockage of continuous training opportunities that would improve the care they provide to vulnerable communities.

Based on these findings, we recommend four concrete actions to improve antimicrobial stewardship. First, we recommend national and international governments as well as health practitioners to identify knowledge gaps in various efforts to tackle AMR particularly in low-income settings. Our framework can help analyse what kind of knowledge needs to flow to whom in order to improve the national and international efforts to improve antimicrobial use. Second, national and sub-national governments need to develop appropriate biomedical training along with antimicrobial use guidelines that are appropriate and relevant for IPs and other such community based practitioners. This will require working with IPs systematically, possibly with digital technologies, to track the care they provide to patients and integrate them into national health systems, and provide appropriate training to them so that the quality of primary care improves for marginalised communities. Third, IPs need to be seen as a source of vital information on local infection patterns. Data collection from IPs may be facilitated by a use of digital technology, and will allow national surveillance agencies to detect patterns of infection and antibiotic resistance. Such insights from "the bottom up" can inform tailored strategies for AMR surveillance for a resource-constrained setting. Fourth, a continuous dialogue needs to inform policy makers, practitioners and researchers how recognising IPs can create a mutual benefit for formal medical professionals and pharmaceutical companies. This will likely require engagement between the formal and informal sectors, possibly facilitated by an NGO and/or research communities, to co-develop solutions against AMR. In doing so, IPs should be considered as a critical source of information that informs policy makers regarding the empirical reality of healthcare in marginalised, though extensive rural settings.

CRediT authorship contribution statement

Gautham Meenakshi: Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Ebata Ayako:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Hennessey Mathew:** Writing – review & editing, Validation, Data curation. **Jung Ann-Sophie:** Writing – review & editing, Validation, Data curation. **Bloom Gerald:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Bhattacharyya Sanghita:** Writing – review & editing, Supervision, Resources, Funding acquisition.

Declaration of Competing Interest

The authors declare no competing interests with regards to this manuscript.

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