

ANTIMICROBIAL PRESCRIBING PATTERNS IN COMPLICATED CELLULITIS: A PROSPECTIVE OBSERVATIONAL STUDY FROM A TERTIARY CARE TEACHING HOSPITAL IN KARNATAKA, INDIA

**Dr. Gajanan S. Kumbar¹, Dr. Seema Hirakannavar^{2*}, Dr. Ramkumar Muddapur²,
Dr. Mallappa Shalavadi³, Dr. Raghavendra S. Hegde²**

¹PharmD Intern, Department of Pharmacy Practice, BVV Sangha's Hanagal Shri Kumareshwar College of Pharmacy, Bagalkot, Karnataka 587101, India.

²Assistant Professor, Department of Pharmacy Practice, BVV Sangha's Hanagal Shri Kumareshwar College of Pharmacy, Bagalkot, Karnataka 587101, India.

³Associate Professor and Head of the Department, Department of Pharmacy Practice, BVV Sangha's Hanagal Shri Kumareshwar College of Pharmacy, Bagalkot, Karnataka 587101, India.

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***Corresponding Author**

Seema Hirakannavar

Assistant Professor, Department of Pharmacy Practice, BVV Sangha's Hanagal Shri Kumareshwar College of Pharmacy, Bagalkot, Karnataka 587101, India.

SYHirakannavar123@gmail.com



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ABSTRACT

Objectives: To characterise the spectrum, frequency and route of antimicrobial agents prescribed for inpatients with cellulitis and its complications at a tertiary care teaching hospital; to document culture-identified multidrug-resistant (MDR) pathogen profiles; to quantify antimicrobial consumption using defined daily dose (DDD) methodology; and to identify clinical predictors of prolonged hospitalisation and intravenous antimicrobial use. **Methods:** A prospective observational study was conducted in the Department of Surgery, S.N.M.C. & H.S.K. Hospital and Research Centre, Bagalkot, Karnataka, India, over six months (February to July 2025). Forty consecutive inpatients with cellulitis and its complications were enrolled. Descriptive statistics, chi-square test and Fisher exact test were applied ($p < 0.05$). Antimicrobial consumption was quantified as total defined daily doses (DDDs) and expressed as the proportional share attributable to each agent and to each AWARe category, using World Health Organisation (WHO)

Anatomical Therapeutic Chemical (ATC)/DDD index 2023 values. **Key Findings:** The cohort comprised 34 males (85%) and 6 females (15%); 75% were aged 41 to 80 years and 75% had

at least one comorbidity. Necrotising fasciitis constituted 45% of presentations; lower extremity involvement occurred in 90% of patients. Twenty antimicrobial agents were prescribed across 121 drug encounters (mean 3.02 per patient); 83.5% were administered intravenously. Piperacillin–tazobactam (18.03%), metronidazole (13.22%) and linezolid (10.74%) dominated prescribing by frequency, while tigecycline recorded the highest consumption by volume (216.0 total DDDs). Among 14 patients (35%) with culture results, nine (64.3%) harboured MDR organisms — including extensively drug-resistant (XDR) *Klebsiella pneumoniae*, XDR *Acinetobacter baumannii*, methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE) — with tigecycline serving as the sole effective salvage agent across all five resistant pathogen categories simultaneously. Cellulitis severity significantly predicted intravenous route use ($\chi^2=10.709$, $df=2$, $p=0.005$); comorbidity showed a gradient towards prolonged hospitalisation that did not reach statistical significance ($\chi^2=8.523$, $df=6$, $p=0.202$). Access-category agents accounted for only 22.8% of total consumption, against the WHO global target of at least 60%. Conclusions: A critically high MDR pathogen burden drives heavy reliance on last-resort antimicrobials in this setting, with tigecycline functioning as the definitive salvage agent across multiple resistant pathogen categories simultaneously. Structured antimicrobial stewardship, universal pre-antibiotic culture sampling and evidence-based de-escalation protocols are urgently required.

KEYWORDS: antimicrobial prescribing; cellulitis; antimicrobial stewardship; multidrug resistance; tigecycline; defined daily dose; pharmacoepidemiology; pharmacy practice; necrotising fasciitis.

INTRODUCTION

Cellulitis is an acute bacterial infection of the dermis and subcutaneous tissues, presenting with localised warmth, erythema, oedema and tenderness. It is among the most common indications for inpatient antibiotic therapy globally, accounting for an estimated 2% of emergency hospital admissions and generating substantial resource utilisation.^[1,2] Population based surveillance has documented cellulitis incidence rates of approximately 24.6 cases per 1,000 person-years, with lower limb involvement in nearly 40% of cases.^[3] In 2021, cellulitis was estimated to cause approximately 28,900 deaths and accounted for 551,000 disability-adjusted life years globally.^[4]

The clinical spectrum ranges from uncomplicated non-purulent infection to life-threatening necrotising fasciitis, a rapidly progressive infection requiring emergency surgical

debridement alongside broad-spectrum antimicrobial therapy.^[5,26] Non-purulent cellulitis is predominantly caused by beta-haemolytic streptococci; purulent cellulitis is most frequently staphylococcal; and necrotising fasciitis typically involves polymicrobial mixtures of aerobic and anaerobic organisms.^[5,6] Community-acquired methicillin-resistant *Staphylococcus aureus* (CA-MRSA) has increasingly been identified in severe necrotising presentations, further narrowing effective therapeutic options.^[7] Established risk factors for lower limb disease include oedema, venous insufficiency, obesity and prior episodes.^[29]

In South Asian tertiary care settings, the challenge is amplified by high endemic prevalence of multidrug-resistant (MDR) pathogens. *Acinetobacter baumannii* and *Klebsiella pneumoniae* exhibit carbapenem resistance rates exceeding 80% at some centres; MRSA constitutes 40% to 83% of *Staphylococcus aureus* isolates; and vancomycin-resistant *Enterococcus* (VRE) is an emerging nosocomial pathogen.^[8,11] These resistance patterns routinely necessitate empirical use of last-resort agents from the outset of treatment, with profound implications for antimicrobial stewardship.^[12]

Pharmacists and pharmacy practice researchers occupy a critical stewardship role in documenting and challenging prescribing practices. Prescribing-pattern studies generate institution-specific baseline data on which stewardship interventions depend. Without knowing which agents are being prescribed, at what frequency and by which route, stewardship teams cannot prioritise de-escalation targets, calibrate educational interventions or monitor consumption trends.^[12,13] Despite this recognised need, systematic DDD-quantified prescribing-pattern studies specifically addressing complicated cellulitis in South Asian tertiary care settings remain sparse.^[14,15,24]

This study was therefore undertaken with four objectives: to characterise the spectrum, frequency and route of antimicrobial agents prescribed for inpatients with cellulitis and its complications; to document culture-identified MDR resistance profiles and salvage strategies employed; to quantify antimicrobial consumption using the WHO defined daily dose methodology classified by the AWaRe framework; and to identify clinical predictors of prolonged hospitalisation and intravenous antimicrobial use, providing an evidence base for a pharmacist-led stewardship programme.

METHODS

Study Design and Setting

A prospective observational study was conducted in the Department of Surgery, S.N.M.C. & H.S.K. Hospital and Research Centre, Bagalkot, Karnataka, India. This is a government-affiliated tertiary care teaching hospital that predominantly treats rural patients across northern Karnataka. The study period was from February 2025 to July 2025 (six months). The study is reported in accordance with the STROBE statement for observational studies.^[30]

Participants

Consecutive patients of all ages admitted to the Department of Surgery with a clinical diagnosis of cellulitis, purulent cellulitis or necrotising fasciitis were screened for eligibility. Inclusion criteria were: inpatient admission with a documented diagnosis of cellulitis or its complications; age of one year or above; and written informed consent (from adults) or written parental/guardian consent with patient assent (for minors). Patients were excluded if they were managed exclusively as outpatients; declined consent; had burn injuries involving more than 20% total body surface area or full-thickness burns; had ischaemic limb ulcers without overlying soft tissue infection; or had gas gangrene without concomitant cellulitis.

Data Collection

A pre-validated structured case record form was used to collect: demographic data (age, sex); comorbidities (diabetes mellitus, hypertension, or combined); cellulitis classification; anatomical site; all antimicrobials prescribed (drug, dose, route, frequency, duration and any escalation or de-escalation); culture-sensitivity results; treatment outcome (improved and discharged; transferred; left against medical advice; in-hospital death); and length of hospital stay (LOS). Data were collected at admission and updated daily until the terminal event.

Classification of Cellulitis Severity

Cellulitis was classified in accordance with the 2014 Infectious Diseases Society of America (IDSA) skin and soft tissue infection guidelines:^[5] non-purulent (erythema, warmth and oedema without purulent exudate or abscess); purulent (associated with abscess or purulent discharge); and necrotising fasciitis (confirmed at surgical exploration demonstrating fascial necrosis, with or without gas on imaging).

Definition of Antimicrobial Resistance Phenotypes

Isolates were classified as multidrug-resistant (MDR) where non-susceptibility was demonstrated to at least one agent in three or more antimicrobial categories, and as extensively drug-resistant (XDR) where non-susceptibility was demonstrated to at least one agent in all but two or fewer categories, in accordance with the international expert proposal for interim standard definitions.^[31]

Sample size justification

This was a prospective census-based pilot study enrolling all eligible consecutive admissions during the six-month study window. No formal a priori power calculation was performed, as the study aimed to characterise prescribing patterns and generate baseline data for stewardship planning rather than test a directional hypothesis, consistent with established methodology for institutional prescribing-pattern studies.^[14,15] Sensitivity analysis indicated adequate statistical power to detect the association between cellulitis severity and route of administration at the observed effect size with $n=40$; the study was not powered to detect associations of smaller magnitude, such as that between comorbidity and length of stay.

Statistical analysis

Data were entered in Microsoft Excel 2021 and analysed using OpenEpi version 3.01. Descriptive statistics (frequencies, percentages, means $\pm$ standard deviations) were computed for all variables. Associations between categorical variables were assessed using the Pearson chi-square (χ^2) test; Fisher exact test was applied where any expected cell count fell below five. A two-tailed significance level of $p<0.05$ was used throughout; $p<0.01$ was considered highly significant. Antimicrobial consumption was quantified as total defined daily doses (DDDs), calculated as total grams consumed $\div$ WHO DDD in grams, using ATC/DDD index 2023 values,^[16] and expressed as the proportion of total DDDs attributable to each agent and to each WHO AWaRe category.^[23]

Ethical approval

Ethical approval was granted by the Institutional Ethics Committee (IEC) of BVV Sangha's Hanagal Shri Kumareshwar College of Pharmacy, Bagalkot, Karnataka (Reference No: HSKCOP/IEC/25/11). All adult participants provided written informed consent prior to enrolment. Written parental or guardian consent plus patient assent were obtained for paediatric participants. Clinical photographs were obtained under individual written patient consent specifically for publication. Patient data were anonymised throughout. The study was conducted in accordance with the Declaration of Helsinki.

RESULTS

Patient Demographics and Comorbidities

Forty patients were enrolled consecutively during the study period. The cohort was predominantly male (n=34, 85%); the age distribution was skewed towards older adults, with the 61–80-year band being the largest group (n=17, 42.5%). Three-quarters of patients (n=30, 75%) had at least one comorbidity: diabetes mellitus alone was present in 15 patients (37.5%), hypertension alone in 8 (20.0%), and combined diabetes plus hypertension in 7 (17.5%). Demographic data are presented in Table 1.

Table 1: Demographic characteristics, sex, and comorbidity profile of the study cohort (N=40).

Characteristic	n (N=40)	%
Age group (years)		
≤20	4	10.0
21–40	4	10.0
41–60	13	32.5
61–80	17	42.5
>80	2	5.0
Total	40	100.0
Sex		
Male	34	85.0
Female	6	15.0
Total	40	100.0
Comorbidities		
Diabetes mellitus (DM) alone	15	37.5
Hypertension (HTN) alone	8	20.0
Combined DM + HTN	7	17.5
None	10	25.0
Total	40	100.0

DM, diabetes mellitus; HTN, hypertension.

Clinical Features and Treatment Outcomes

Necrotising fasciitis was the predominant presentation (n=18, 45%), followed by purulent cellulitis (n=12, 30%) and non-purulent cellulitis (n=10, 25%). Lower extremity involvement occurred in 36 of 40 patients (90%), a predominance consistent with that reported in other series.^[25] Wound infection was the precipitating aetiology in 12 patients (30%); sepsis complicated admission in five patients (12.5%).

The majority of patients improved and were discharged (n=32, 80%). Two patients (5%) died during admission — both presenting with necrotising fasciitis complicated by pan-resistant

Gram-negative bacteraemia. Four patients (10%) were transferred to a higher centre for further surgical management and two (5%) left against medical advice. The median LOS was 14 days (range 3–42 days); 45% of patients (n=18) required more than 14 days of hospitalisation. Clinical features and outcomes are presented in Table 2.

Table 2: Clinical features, cellulitis classification, anatomical site, treatment outcomes and length of hospital stay (N=40).

Variable	n (N=40)	%
Type of cellulitis		
Non-purulent cellulitis	10	25.0
Purulent cellulitis	12	30.0
Necrotising fasciitis	18	45.0
Anatomical site		
Lower extremity (total)	36	90.0
Left lower limb	25	62.5
Right lower limb	13	32.5
Upper extremity / other	4	10.0
Precipitating cause / presenting complication		
Wound infection	12	30.0
Necrotising fasciitis at presentation	15	37.5
Sepsis secondary to cellulitis	5	12.5
Abscess formation	3	7.5
Uncomplicated cellulitis	10	25.0
Treatment outcome		
Improved and discharged	32	80.0
Transferred to higher centre	4	10.0
Left against medical advice (LAMA)	2	5.0
In-hospital death	2	5.0
Length of hospital stay (LOS)		
≤7 days	8	20.0
8–14 days	14	35.0
>14 days	18	45.0
Median LOS (days), range	14 (3–42)	—

LAMA, left against medical advice; LOS, length of hospital stay. Within the anatomical site and precipitating cause blocks the categories are not mutually exclusive: patients with involvement at more than one site, or with more than one precipitating cause or presenting complication, are counted under each applicable category. Percentages in those two blocks are calculated against N=40 and therefore do not total 100%.

Antimicrobial Prescribing Patterns

Across 40 patients, 121 antimicrobial drug encounters were recorded involving 20 distinct agents from 10 pharmacological classes. The mean number of antimicrobials per patient was 3.02 (range 1–9). Treatment escalation — defined as a change in antimicrobial class or addition of a new agent based on culture results or clinical deterioration — occurred in 10 patients (25%). Intravenous formulations accounted for 101 of 121 encounters (83.5%); oral agents for the remaining 20 (16.5%).

Piperacillin–tazobactam was the most frequently prescribed agent (n=22, 55%; 18.03% of all encounters), administered exclusively intravenously. Metronidazole was prescribed in 16 patients (13.22%), invariably intravenously, reflecting anaerobic co-infection in necrotising presentations. Linezolid was used in 13 patients (10.74%): nine intravenously and four orally, indicating planned intravenous-to-oral step-down. Tigecycline was prescribed to 12 patients (9.92%) exclusively intravenously, and meropenem to 14 patients (11.57%). A clear gradient was observed between cellulitis severity and antimicrobial burden, patients with more severe presentations receiving a greater number of agents. The complete prescribing pattern is presented in Table 3.

Table 3: Antimicrobial agents prescribed: class, frequency and route of administration (40 patients; 121 drug encounters; 20 distinct agents).

Antibiotic class	Agent	Patients (n)	Encounters (%)	IV (n)	PO (n)
Beta-lactams (51 encounters, 42.15%)					
	Piperacillin–tazobactam	22	18.03	22	0
	Meropenem	14	11.57	14	0
	Cefoperazone–sulbactam	5	4.13	5	0
	Amoxicillin–clavulanate	4	3.31	2	2
	Ceftriaxone	2	1.65	2	0
	Cefuroxime	2	1.65	0	2
	Cefotaxime	2	1.65	2	0
Nitroimidazoles (16 encounters, 13.22%)					
	Metronidazole	16	13.22	16	0
Oxazolidinones (13 encounters, 10.74%)					
	Linezolid	13	10.74	9	4
Glycylcyclines (12 encounters, 9.92%)					
	Tigecycline	12	9.92	12	0
Lincosamides (8 encounters, 6.61%)					
	Clindamycin	8	6.61	3	5
Fluoroquinolones (8 encounters, 6.61%)					

	Levofloxacin	4	3.31	2	2
	Ciprofloxacin	3	2.48	2	1
	Ofloxacin	1	0.83	0	1
Aminoglycosides (6 encounters, 4.96%)					
	Amikacin	4	3.31	4	0
	Gentamicin	2	1.65	2	0
Macrolides, tetracyclines and other (7 encounters, 5.79%)					
	Clarithromycin	2	1.65	2	0
	Minocycline	2	1.65	0	2
	Erythromycin	1	0.83	0	1
	TMP-SMX	2	1.65	2	0
Total (20 agents)			121	101 (83.5%)	20 (16.5%)

IV, intravenous; PO, oral; TMP-SMX, trimethoprim-sulfamethoxazole. Percentages calculated against total 121 drug encounters. Some patients received two or more agents concurrently.

Antimicrobial Consumption and AWaRe Classification

Expressed as total defined daily doses, tigecycline recorded the highest consumption (216.0 DDDs), marginally exceeding piperacillin–tazobactam (212.1 DDDs), followed by meropenem and metronidazole (112.0 DDDs each) and linezolid (104.0 DDDs). Under the WHO AWaRe 2023 classification, Reserve-category agents (tigecycline and linezolid) accounted for 38.4% of total consumption and Watch-category agents for 38.9%, leaving only 22.8% attributable to Access-category agents. This profile reflects the severity of the admitted case-mix (Table 6).

Culture-Sensitivity Reports and MDR Pathogen Profiles

Culture-sensitivity reports were available for 14 of 40 patients (35.0%), yielding 12 bacterial isolates. Of the 14 patients tested, nine (64.3%) harboured at least one MDR organism, the 12 isolates comprising 10 with an MDR, XDR, MRSA or VRE phenotype and two fully susceptible organisms. XDR *Klebsiella pneumoniae* and XDR *Acinetobacter baumannii* were each isolated from two patients, demonstrating resistance across all available antibiotic classes except tigecycline. Three VRE (*Enterococcus faecalis*) isolates were identified; linezolid with or without tigecycline was the only effective option. MRSA was identified in one patient and MDR *Staphylococcus aureus* in one patient, both responding only to tigecycline. Tigecycline thus served as the sole effective salvage agent across five distinct MDR pathogen categories simultaneously — the principal clinical finding of this study. Resistance profiles and salvage strategies are presented in Table 4.

Table 4: Microbiological resistance profiles and salvage antimicrobial strategies in culture-positive patients (culture reports available n=14; MDR-positive patients n=9; isolates n=12, of which 10 multidrug-resistant).

Organism (n isolates)	Phenotype	Resistant antibiotic classes / agents	Salvage therapy
<i>Klebsiella pneumoniae</i> (2)	XDR	Penicillins, all cephalosporins, carbapenems, fluoroquinolones, aminoglycosides, sulphonamides	Tigecycline ± gentamicin
<i>Klebsiella pneumoniae</i> — MDRB (1)	MDR	Piperacillin–tazobactam, ceftriaxone, cefoperazone–sulbactam, cefepime, imipenem, meropenem, amikacin, gentamicin, ciprofloxacin, levofloxacin, minocycline, TMP-SMX	Tigecycline
<i>Staphylococcus aureus</i> — MRSA (1)	MRSA	Oxacillin/cefoxitin, benzylpenicillin, ciprofloxacin, erythromycin	Tigecycline
<i>Staphylococcus aureus</i> (1)	MDR	Benzylpenicillin, oxacillin, teicoplanin, clindamycin, vancomycin, TMP-SMX	Tigecycline + gentamicin
<i>Enterococcus faecalis</i> — VRE (3)	VRE	Vancomycin, ciprofloxacin, levofloxacin, erythromycin, daptomycin, tetracycline, nitrofurantoin, teicoplanin	Linezolid / Tigecycline
<i>Acinetobacter baumannii</i> (2)	XDR	Piperacillin–tazobactam, cefoperazone–sulbactam, cefepime, imipenem, meropenem, ciprofloxacin, gentamicin, amikacin, levofloxacin, TMP-SMX	Tigecycline
<i>Providencia rettgeri</i> (1)	Susceptible	No resistance identified	Piperacillin–tazobactam
<i>Enterococcus</i> spp. (1)	Susceptible	No resistance identified	Ciprofloxacin + linezolid

XDR, extensively drug-resistant; MDR, multidrug-resistant; MDRB, multidrug-resistant bacteria; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus*; TMP-SMX, trimethoprim-sulfamethoxazole.

Statistical Associations

Comorbidity was not significantly associated with prolonged LOS ($\chi^2=8.523$, $df=6$, $p=0.202$), although a consistent gradient was observed: patients with combined diabetes plus hypertension experienced the longest admissions and those without comorbidity the shortest. Cellulitis severity was highly significantly associated with route of administration ($\chi^2=10.709$, $df=2$, $p=0.005$): all patients with necrotising fasciitis received exclusively intravenous therapy, while oral or step-down use occurred only in non-purulent presentations. Sex was not significantly associated with cellulitis type ($\chi^2=2.397$, $df=2$, $p=0.302$), nor was

age group ($\chi^2=7.261$, $df=8$, $p=0.509$). Culture-guided versus empiric therapy was not significantly associated with clinical outcome (Fisher exact $p=0.689$), reflecting the small culture subgroup ($n=14$) and the overriding influence of disease severity on outcome. All chi-square results are presented in Table 5.

Table 5: Chi-square analysis: associations between key clinical variables.

Association tested	χ^2 value	df	p-value	Interpretation
Comorbidity vs length of hospital stay	8.523	6	0.202	Not significant
Cellulitis severity vs route of administration	10.709	2	0.005**	Highly significant
Sex vs cellulitis type	2.397	2	0.302	Not significant
Age group vs cellulitis type	7.261	8	0.509	Not significant
Culture-guided vs empiric therapy vs outcome†	—	—	0.689	Not significant (Fisher exact)

df, degrees of freedom. ** $p<0.01$, highly significant. †Fisher exact test applied where expected cell count <5 .

Table 6: Antimicrobial consumption expressed as WHO defined daily doses (DDDs) with AWARe classification.

Antimicrobial agent	WHO DDD (g)	Total DDDs	% of total DDDs	AWaRe category
Tigecycline	0.1	216.0	25.9	Reserve
Piperacillin–tazobactam	14.0	212.1	25.4	Watch
Meropenem	3.0	112.0	13.4	Watch
Metronidazole (IV)	1.5	112.0	13.4	Access
Linezolid	1.2	104.0	12.5	Reserve
Amikacin	1.0	42.0	5.0	Access
Clindamycin	1.8	36.0	4.3	Access
Total	—	834.1	100.0	—

WHO ATC/DDD 2023 index values used. Total DDDs calculated as total grams consumed ÷ WHO DDD in grams. Percentages are of the cohort total of 834.1 DDDs and may not sum to exactly 100.0 owing to rounding. AWARe: Access = first-line; Watch = higher AMR risk; Reserve = last-resort.

DISCUSSION

The principal finding of this prospective prescribing-pattern study is that tigecycline functioned simultaneously as the sole effective salvage agent for five distinct MDR pathogen categories — XDR *Klebsiella pneumoniae*, XDR *Acinetobacter baumannii*, MRSA, MDR *Staphylococcus aureus* and VRE — in a single six-month cohort of 40 hospitalised patients

with cellulitis. This convergence of multiple resistant pathogens on a single last-resort agent represents a critically narrow therapeutic margin with immediate implications for antimicrobial stewardship practice. That tigecycline also recorded the highest consumption of any agent by volume compounds the concern: the agent of last resort is, in this setting, the agent most used.

The magnitude of MDR burden is consistent with contemporary resistance surveillance data from South Asian tertiary care hospitals. Published studies have reported carbapenem resistance in *Acinetobacter baumannii* exceeding 80% and MRSA prevalence among *Staphylococcus aureus* isolates ranging from 40% to 83% at tertiary care centres across India.^[8-9] These resistance rates compel clinicians to initiate broad-spectrum combinations empirically before culture results are available, exactly as documented in this cohort. Tigecycline's ability to overcome both efflux-mediated and ribosomal tetracycline resistance mechanisms confers broad-spectrum activity against MRSA, VRE and carbapenem-resistant Gram-negative pathogens,^[17] and clinical studies confirm cure rates of approximately 90% in necrotising soft tissue infections caused by MDR bacteria.^[18] These findings are corroborated by the current real-world data.

The predominance of necrotising fasciitis (45%) is substantially higher than rates reported in high-income country cellulitis series, where necrotising presentations typically account for 5–10% of admitted cases.^[6] This reflects referral bias inherent to a tertiary surgical unit serving a predominantly rural catchment area with delayed presentations. A comparable pattern was documented at tertiary surgical units in South India where complicated presentations dominated admissions.^[19] The two in-hospital deaths, both patients with pan-resistant Gram-negative bacteraemia complicating necrotising fasciitis, highlight the outcome consequences when advanced infection converges with exhausted antimicrobial options.

From a pharmacy practice perspective, the most actionable finding is that 65% of all high-tier antimicrobial prescribing decisions were made without microbiological guidance, as only 35% of patients had cultures obtained. Of those tested, 64.3% harboured MDR organisms, suggesting the true MDR burden among untested patients may be substantially larger. The Indian Council of Medical Research (ICMR) National Treatment Guidelines recommend cultures be obtained prior to antibiotic initiation in all hospitalised skin and soft tissue infection cases.^[20] A pharmacist-driven pre-antibiotic culture bundle — mandating specimen collection before the first antimicrobial dose in every admitted cellulitis case — represents

the primary stewardship intervention identified by this study. Low culture rates in cellulitis have been reported internationally, with Wiederhold *et al.* documenting similar suboptimal microbiological sampling at a Danish emergency department, suggesting this is a global challenge.^[15]

The association between comorbidity and prolonged LOS did not reach statistical significance in this cohort ($\chi^2=8.523$, $df=6$, $p=0.202$). The direction of the gradient was nonetheless consistent, with combined comorbidity associated with the longest admissions, and is biologically plausible: diabetes mellitus impairs neutrophil chemotaxis and phagocytosis, while hypertension and peripheral vascular disease compromise skin microcirculation and antimicrobial tissue penetration.^[21-22,27] A comparable association reached significance in the larger European series reported by Carratala *et al.*^[22] The absence of statistical significance in a cohort of this size should therefore be read as a limitation of power rather than as evidence of no association, and pharmacists may still contribute to reducing LOS through glycaemic optimisation consultations, therapeutic drug monitoring in patients with altered pharmacokinetics, and proactive intravenous-to-oral switch planning. The significant association between severity and intravenous route of administration ($\chi^2=10.709$, $df=2$, $p=0.005$) confirms appropriate clinical stratification and provides a benchmark for future de-escalation audits.

WHO AWaRe consumption data reveal a profile dominated by Watch-category and Reserve-category agents. The WHO global target of at least 60% of antibiotic use being Access-category agents^[23] is not approached in this case-mix, Access agents accounting for only 22.8% of total consumption — a shortfall of some 37 percentage points. This benchmark is not achievable here without structural changes to culture practices and de-escalation protocols, yet it provides a measurable gap that a future stewardship programme can quantify and reduce.

That culture-guided therapy was not associated with statistically superior outcomes (Fisher exact $p=0.689$) should be interpreted with caution. The subgroup with available culture data was small ($n=14$), limiting statistical power to detect a meaningful difference. Furthermore, the relationship between pathogen-directed therapy and clinical outcome in cellulitis is complex: empiric therapy is often initiated before cultures mature, and the most severe patients are precisely those most likely to have cultures sent. The absence of a statistically

significant difference does not imply clinical equivalence; it reflects the constraints of a small observational cohort.

Limitations of this study include single-centre design with a specific referral pattern, a sample size of 40 patients appropriate for a pilot study but limiting subgroup statistical power, the availability of culture data for only 35% of patients, and the absence of post-discharge outcome tracking. Recurrence, which prophylactic strategies may influence, ^[28] was not assessed. Future multicentre studies with mandatory pre-antibiotic culture sampling and standardised long-term outcome recording are recommended.

CONCLUSIONS

Antimicrobial prescribing in hospitalised cellulitis at this tertiary care surgical setting is characterised by high-intensity intravenous broad-spectrum therapy driven by a critically high MDR pathogen burden and inadequate pre-antibiotic microbiological sampling. Tigecycline has emerged as the de facto last-resort salvage agent across five simultaneously occurring MDR pathogen categories, and is at the same time the most consumed agent by volume — a finding with immediate implications for stewardship policy and antimicrobial procurement planning. Comorbidity showed a consistent but statistically non-significant gradient towards prolonged hospitalisation, and remains a plausible target for pharmacist-led management interventions that adequately powered studies should examine. A pharmacist-driven pre-antibiotic culture bundle should be the first and most impactful stewardship intervention implemented at this centre. This study demonstrates that clinical pharmacy research — conducted by PharmD students and faculty in partnership with surgical teams — can generate institution-specific stewardship evidence that is directly applicable to practice improvement.

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DECLARATIONS

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Conflict of interest: All authors declare no competing interests.

Ethics approval: Granted by the Institutional Ethics Committee (IEC) of BVV Sangha's Hanagal Shri Kumareshwar College of Pharmacy, Bagalkot, Karnataka (Reference No: HSKCOP/IEC/25/11). The study was conducted in accordance with the Declaration of Helsinki.

Data availability: The dataset on which the conclusions of this manuscript rely is available from the corresponding author on reasonable request.

Author Contributions

Gajanan S. Kumbar: Conceptualisation, Data curation, Formal analysis, Writing – original draft.

Seema Hirakannavar: Methodology, Supervision, Writing – review and editing.

Ramkumar Muddapur: Investigation, Writing – review and editing.

Mallappa Shalavadi: Conceptualisation, Supervision, Project administration, Writing – review and editing.

Raghavendra S. Hegde: Conceptualisation, Methodology, Supervision, Writing – review and editing.

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