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Outpatient parenteral antimicrobial therapy: development and experience from a tertiary care center

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ABSTRACT:

Outpatient parenteral antimicrobial therapy (OPAT) is an effective strategy for managing infections that require prolonged intravenous (IV) therapy, while reducing hospital length of stay and healthcare costs. Successful OPAT implementation requires careful patient selection, a structured multidisciplinary team, and individualized models of care tailored to both infection complexity and patient-specific factors.

We provide a narrative overview of OPAT management, integrating current guideline recommendations and evidence from the literature.

OPAT represents a valid model of care for patients requiring prolonged IV antimicrobial therapy, enabling a safe transition from inpatient to outpatient settings without compromising clinical outcomes. Moreover, it delivers substantial organizational and economic benefits, with marked reductions in hospital bed stays and associated costs. OPAT is a safe and effective alternative to prolonged hospitalization, especially for complex infections caused by pathogens with limited therapeutic options.

Keywords: Outpatient parenteral antibiotic therapy, Antimicrobial therapy, Outpatient antimicrobial therapy, Therapeutic drug monitoring, Nursing outpatient management.

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INTRODUCTION

Outpatient parenteral antinfective treatment (OPAT) can be a challenging setting for clinicians to manage. In this setting, parenteral antimicrobial therapy could be the optimal option, with many advantages over oral therapy, particularly in cases with limited therapeutic options. OPAT is a care model that facilitates the administration of intravenous (IV) antimicrobial agents in non-hospitalized settings, enabling patients to receive prolonged parenteral treatment at home, in outpatient infusion facilities, or through supervised self-administration. This approach has a primary aim: to avoid or reduce hospital length of stay while maintaining clinical efficacy and safety of the treatment[1,2]. OPAT is primarily indicated for infections that require prolonged IV therapy when effective oral treatment options are unavailable or impractical[3]. Common indications include acute bacterial skin and skin soft-tissue infections (ABSSSI), complicated urinary tract infections (cUTI) or prostatitis, bone and joint infections, diabetic foot infections, lower respiratory infections such as bronchiectasis exacerbations or cystic fibrosis, infective endocarditis (IE), and bloodstream infections (BSI)[3-5]. Safety remains a central component of OPAT programs. Vascular access-related complications represent the most frequent adverse events, while drug-related toxicities are less common but clinically relevant, particularly during the early phases of therapy[6,7]. These findings underscore the need for standardized monitoring protocols and early surveillance, especially within the first two weeks of treatment. Moreover, OPAT offers substantial additional advantages, including reduced risk of healthcare-associated infections and economic benefits, as it consistently demonstrates marked reductions in healthcare costs and hospital bed utilization compared with equivalent inpatient care. The use of elastomeric infusion devices has been associated with cost reductions of up to 92% compared with conventional inpatient treatment, resulting in approximately €700,000 in savings. While the economic benefits of OPAT are well established, another driver of its adoption is the potential to improve patients' quality of life by avoiding prolonged hospitalization[6].

OPAT can be delivered through multiple models, including self-administration at home (with patient or caregiver training), home visits by nurses, outpatient infusion centers, or hospital-based clinics[8]. Notably, self-administration demonstrates outcomes comparable to or superior to those of healthcare professional-administered therapy[8]. The choice of delivery model depends on patient capabilities, infection complexity, antimicrobial requirements, insurance coverage, and available resources. Successful OPAT delivery relies on careful patient selection, structured multidisciplinary teams, and individualized models of care tailored to infection complexity and patient capabilities. All these factors are fundamental to improving patient adherence and quality of life, reducing the risk of complications, enhancing treatment safety, and ultimately achieving an adequate clinical response. Depending on the healthcare system, the choice of OPAT delivery model is influenced by patient capability, infection complexity, antimicrobial requirements, insurance coverage, and available resources[1]. Successful OPAT implementation requires careful patient selection, a structured multidisciplinary team, and individualized models of care tailored to both infection complexity and patient-specific factors. Together, these elements are essential for optimizing adherence and quality of life, minimizing complications, ensuring treatment safety, and ultimately achieving favorable clinical outcomes.

METHODS

A comprehensive literature search was conducted to identify relevant studies and guidelines concerning the OPAT. The search strategy was implemented using online databases (PubMed/MEDLINE, Scopus, Google Scholar) and expert-authored books. The search was not restricted by language or publication date and covered articles up to the cutoff date of January 2025. The search strategy had no time limits or language restrictions. We screened the articles by title, abstract, and full text. After an initial screening of titles and abstracts of published articles, the reviewers evaluated the full articles to determine each study's eligibility for inclusion in this narrative review. A study was included if it was likely to provide valid and valuable information according to the review's objective.

INDICATIONS, RECOMMENDATIONS, AND ELIGIBILITY CRITERIA

The infectious disease specialist must evaluate several conditions, all of which are necessary: a suitable patient and caregiver, clinical condition, type of antibiotic, type of IV access, and choice of device. The indication for OPAT, as well as the selection of the antimicrobial agent and mode of administration, should be prescribed exclusively by an infectious diseases specialist within the referring healthcare institution.

The rationale for this recommendation is supported by evidence showing that infectious disease specialists' review reduces unnecessary OPAT prescriptions (by up to 24% in some studies[1]), facilitates timely transition to oral therapy when appropriate, and is not associated with worse clinical outcomes[1].

Eligible conditions include infections requiring prolonged IV antimicrobial therapy but not necessitating inpatient hospitalization, such as IE, osteomyelitis and spondylodiscitis, prosthetic and device-related infections (PJI), cerebral, pulmonary, abdominal, or renal abscesses, chronic prostatitis, bronchiectasis and cystic fibrosis infections-related, as well as selected diseases in onco-hematological patients[3,5,9,10].

An adequate home-care setting and patient compliance are essential prerequisites[11-13]. A comprehensive assessment of the domestic environment and the caregiver's and patient's ability to adhere to the proposed therapeutic regimen should be conducted jointly by the discharging ward physician, the infectious diseases specialist, and the nursing staff. We suggest that patients and caregivers receive structured education and training before discharge, supported by written and audiovisual instructional materials.

Venous access must be secured through a midline catheter or a central venous catheter, including peripherally inserted central catheters (PICC) or port-a-cath devices[1]. The use of mini-midline catheters may be considered on a case-by-case basis, depending on the antimicrobial chosen. Peripheral venous catheters may be used only as a temporary bridging option for up to 96 hours in the event of obstruction of the primary vascular access[14,15].

It is important to note that, to enhance the safety of OPAT administration, the first antimicrobial administration, including the initiation of the first elastomeric pump infusion, should be performed in the inpatient setting[6,16]. Regular clinical and laboratory monitoring is mandatory to detect adverse events, including hematological, renal, or hepatic toxicity. Monitoring schedules could be individualized based on the antimicrobial agent used and the patient's risk profile. Side effects are not infrequent; in a prospective cohort[17], 18% of patients experienced drug-related adverse events, 14.5% of which were clinically significant. Notably, data from the literature indicate that side events peak during the second week of OPAT and subsequently decline, further reinforcing the importance of close surveillance during the initial treatment phase[18].

CONTRAINDICATIONS

OPAT is contraindicated in patients presenting with clinical, organizational, or psychosocial conditions that may compromise safety, adherence, or treatment effectiveness. Major contraindications include, (i) clinical conditions requiring inpatient hospitalization or frequent and intensive clinical monitoring, (ii) inadequate patient adherence or unsuitable home-care setting, including insufficient caregiver competence or availability, poor environmental hygiene, or lack of appropriate conditions for drug storage and administration (e.g., inadequate temperature control), (iii) severe heart failure (New York Heart Association class $\geq$ II), (iv) severe renal impairment (creatinine clearance $<$ 30 mL/min), (v) Severe hepatic dysfunction (Child-Pugh class C), (vi) history of severe drug hypersensitivity reactions, including previous anaphylactic shock, (vii) Unstable vascular access or suspected catheter-related thrombosis, (viii) High bleeding risk, warranting multidisciplinary evaluation (e.g., consultation with a vascular or angiology specialist), (ix) severe psychiatric disorders or active substance use disorder, (x) documented allergy to the selected antimicrobial agent; in cases of proven allergy to an entire antimicrobial class, treatment decisions should be individualized following an evaluation by an infectious diseases specialist[1,8,11].

VASCULAR ACCESS IN OPAT

Antibiotic Selection According to Venous Access and Infusion Feasibility

Antibiotics have intrinsic properties that may influence vascular tolerability. Phlebitogenic potential, pH, and osmolarity are closely associated with the risk of chemical phlebitis, including endothelial damage, local pain, and extravasation. In general, antibiotics are considered highly phlebitogenic when they exhibit a pH $<$ 5 or $>$ 9, or an osmolarity $>$ 600 mOsm/L[19,20].

The impact of these characteristics can be mitigated through specific technical strategies. In particular, increasing the dilution volume significantly reduces the final osmolarity of the infused solution, while exerting a more limited effect on pH. An additional approach is to reduce the infusion rate, allowing a more gradual dilution of the antibiotic in the bloodstream and thereby decreasing local endothelial irritation[19,21-23].

Based on the physicochemical properties of individual antibiotics and real-world clinical experience, commonly used antimicrobial agents can be grouped by phlebitogenic risk (Table 1), with corresponding recommendations for the most appropriate venous access type.

Table 1. Antibiotics and recommended venous access according to phlebitogenic risk[1,24,25].

Group	Recommended venous access	Antibiotics
Group 1	Peripheral venous access is considered safe.	Aztreonam, Caspofungin, Ceftazidime, Ceftazidime/Avibactam, Ceftolozane/Tazobactam, Ceftriaxone, Fluconazole, Levofloxacin, Teicoplanin.
Group 2	Central venous access preferred	Amoxicillin/Clavulanate, Amikacin, Ampicillin, Anidulafungin, Cefazolin, Cefepime, Ciprofloxacin, Daptomycin, Ertapenem, Fosfomycin, Gentamicin, Oxacillin, Piperacillin/Tazobactam
Group 3	Central venous access required	Acyclovir, Ganciclovir, Vancomycin, Amphotericin B

Venous Access Characteristics and Selection

Venous access devices are intravascular devices that allow the administration of medications from an external reservoir into the vascular lumen and can be broadly classified into central and peripheral venous access devices. Central venous access devices (CVADs) include all devices whose catheter tip reaches the superior vena cava, inferior vena cava, or the right atrium, such as peripherally inserted central catheters (PICC), centrally inserted central catheters (CICC), PICC-Ports, CICC-Ports, femoral inserted central catheters (FICC), tunneled central venous catheters, and other long-term central devices. Instead, peripheral venous access devices (PVADs) include all devices whose tip does not extend beyond the subclavian vein. The most commonly used peripheral devices are short peripheral IV cannulae, mini-midline catheters, and midline catheters[26,27]. In the outpatient setting, the routine use of short peripheral cannulae or mini-midline catheters, as well as non-tunneled central venous catheters or femoral central venous catheters, should not be recommended[1,28] because of the increased risk of mechanical and infectious complications[29]. However, short peripheral cannulae and mini-midline catheters may be considered exceptionally and for a limited duration, particularly for once-daily antibiotic administration, as a bridging venous access while awaiting placement of a definitive device for continuous infusion, or, in selected exceptional cases, for continuous infusion, following agreement between the infectious diseases physician and the vascular access team. Types of vascular accesses, their indications, and recommendations are summarized in Table 2.

INFUSION DEVICES AND DELIVERY SYSTEMS (ELASTOMERIC PUMPS AND INFUSION BAGS)

Continuous or prolonged antimicrobial infusions in both inpatient and outpatient settings rely on dedicated infusion delivery systems, primarily elastomeric pumps and infusion bags, that ensure accurate drug administration over time while preserving patient mobility and safety.

Baxter® elastomeric pumps (Baxter International Inc., Deerfield, IL, USA) represent the most widely used systems in clinical practice and are also those for which the largest body of published literature, technical documentation, and real-world OPAT experience is currently available[6,30-32]. Elastomeric pumps allow continuous drug delivery without the need for external power sources. Infusion flow is regulated by an internal flow restrictor, whose performance is influenced by temperature, device positioning, and connector integrity[33]. A summary of Baxter® elastomeric pumps is reported in Table 3.

The preparation of infusion bags must strictly follow the medical prescription and standard procedures for IV drug preparation. Reconstitution and dilution of antimicrobial agents should be performed according to drug-specific stability data and their compatibility with the selected elastomeric pump and infusion duration[3,35-37].

Reconstituted solutions may be stored only within the limits defined by stability data, as summarized in Table 4, to ensure microbiological safety and pharmacological integrity.

After preparation of the elastomeric pump or infusion bag, a series of systematic checks should be performed to ensure patient safety and correct drug delivery. Each

Table 2. Indications for venous access selection according to antibiotic group and treatment characteristics.

Venous access device	Type	Indicated antibiotics	Administration modality	Duration	Notes
Short peripheral IV cannula	Short-term peripheral venous catheter	Group 1-2	Once-daily intermittent infusion	< 72 hours	Use only with adequate dilution; suitable as temporary "bridging" access for continuous infusion *via* elastomeric devices
Mini-midline catheter	Short-term inter-mediate peripheral catheter	Group 1 (continuous infusion); Group 1-2 (once-daily)	Continuous infusion or once-daily intermittent infusion	< 14 days	Appropriate for elastomeric pumps; may serve as bridging access
Midline catheter	Medium-term peripheral venous catheter	Group 1 (preferred); selected Group 2	Continuous infusion (Group 1); intermittent once-daily infusion with high dilution (Group 2)	> 15 days and < 6 weeks	Continuous infusion of Group 2 antibiotics is possible but associated with a higher complication risk
PICC	Medium-term central venous access	Group 1, 2, and 3	Continuous or intermittent infusion	> 14 days and < 6 months	Preferred option for prolonged OPAT and high-risk infusions
Tunneled cuffed central venous catheter	Long-term central venous access	Group 1, 2, and 3	Continuous or intermittent infusion	> 6 months	Indicated for long-term therapies; lowest risk of dislodgement

OPAT=Outpatient Parenteral Antimicrobial Therapy; PICC=Peripherally Inserted Central Catheter.

Table 3. Summary of Baxter® elastomeric pumps used for antimicrobial infusion[34].

Pump model	Volume	Infusion rate	Infusion duration	Main indications	Key technical notes
Baxter LV10 (2C2063KP)	240 mL (min 216 - max 300 mL)	10 mL/h	~20-26 h	Standard continuous OPAT infusion	Flow varies ± 2.3% per °C (tolerance ± 15%); residual > 40 mL at 24 h suggests malfunction; preferable early rather than delayed emptying; Luer Lock must adhere to skin; keep pump at same height as venous access
Baxter Infusor LV 5-7-12 (2C1811K)	240 mL (min 216 - max 300 mL)	5/7/12 mL/h	~20 h (at 12 mL/h)	Alternatively, when LV10 does not fully empty	In OPAT, use 12 mL/h only; all three flow channels must be filled during preparation according to the technical sheet
Baxter LV50 (2C2720K)	250 mL (min 225 - max 275 mL)	50 mL/h	~5 h	Rapid infusions/ high-volume delivery	Same temperature dependence (± 2.3% per °C); Luer Lock regulates flow and must adhere to skin; keep pump at access height

OPAT=Outpatient Parenteral Antimicrobial Therapy.

prepared device should undergo visual inspection to confirm the absence of precipitates, particulate matter, foreign bodies, or any alteration in the expected color of the solution. The integrity of the infusion device must be verified, including the absence of leaks, defects, or damage to connectors and tubing. In addition, compliance with the medical prescription should be carefully checked, ensuring consistency in the drug, dose, diluent, final volume, and infusion modality[38,39]. We recommend at least daily visual inspection of the elastomeric pump to confirm correct device function and the stability of the preparation, with particular attention to the absence of discoloration or precipitate formation over time[35,40]. During administration, the infusion device should be kept close to the patient's body and, whenever possible, maintained at approximately the same height as the catheter insertion site to minimize flow variability and ensure consistent drug delivery[35,41].

Table 4 summarizes examples of antibiotics with recommended dosing, preparation, stability, and venous access.

MANAGEMENT OF COMPLICATIONS

The management of complications during OPAT requires a structured, coordinated approach involving the patient, caregivers, and multiple healthcare professionals across inpatient, outpatient, and community settings. Effective management depends on the timely recognition of complications, their clinical severity, and the patient's overall stability, as well as on the availability of predefined care pathways that facilitate rapid communication and continuity of care.

Complications arising during OPAT may range from mild and self-limited events to potentially life-threatening conditions. For practical purposes, these events can be broadly distinguished as non-urgent or urgent, although clinical judgment remains central in determining the appropriate level of intervention[1,2,17,43,44].

Non-urgent complications are relatively common and often involve issues with drug delivery systems or early laboratory abnormalities. These minor events could occur in 11% to 45% of cases[43,45,46]. These may include incomplete emptying of elastomeric pumps or infusion bags, partial obstruction or dislodgement of the venous access device, low-grade fever, mild mucocutaneous bleeding, dehydration or reduced urine output, and early signs of renal, hepatic, or hematological toxicity[1,17]. In clinically stable patients, such events can usually be managed without immediate hospital admission through close monitoring, temporary modification or suspension of therapy, laboratory reassessment, and planned outpatient evaluation[1]. When venous access dysfunction is suspected, a temporary peripheral venous access device may be considered as a bridging solution while awaiting definitive reassessment or replacement by a vascular access team[47]. Venous access-related complications are the most frequent causes of OPAT interruption[48]. Obstruction or dislodgement of the catheter, in the absence of systemic symptoms, is generally considered a non-urgent event and should be managed through coordinated reassessment by outpatient services, home care providers, and the discharging team[49,50].

Urgent complications, in contrast, include acute clinical conditions such as loss of consciousness, severe allergic or cutaneous reactions, acute abdominal pain, chest pain, dyspnoea, jaundice, hemoptysis, significant bleeding, or evidence of gastrointestinal hemorrhage. These situations require prompt referral to emergency care settings for immediate evaluation and treatment[1,51]. When continuous infusion cannot be immediately resumed, a temporary fractionated dosing regimen may be initiated as a bridging strategy until safe re-establishment of venous access and infusion systems is achieved[1].

Table 4. Antimicrobial agents: dosing, preparation, stability, venous access, and recommendations for OPAT[42].

Drug	Loading dose pre-OPAT	Dosage	Container – dilution, concentration and stability	Stability after reconstitution	Venous access	Recommendations
Aztreonam	2 g in 100 mL NS	6-8 g/day by continuous infusion (adjust for CrCl)	**Elastomeric pump:** up to 50 mg/mL in NS, 240 mL at 10 mL/h for 24 h or 12mL/h for 20h; stable up to 37°C for 24 h. **Infusion bag:** up to 12 mg/mL in a PVC bag with 500 mL NS at 21 mL/h; stable up to 37°C for 24 h.	Stable up to 72 h at 4°C	**Elastomeric:** Midline **Infusion bag:** Midline or mini-midline	Daily dose fractionation: 2 g every 8 h. Flush line 2-3 times/ day. Protect the infusion bag from sunlight.
Piperacillin/ Tazobactam	6.25 g in 100 mL NS over 60 min	18 g/day by continuous infusion (adjust for CrCl)	**Elastomeric pump:** up to 80-10 mg/mL in NS or D5W, 240 mL at 10 mL/h for 24 h or 12 mL/h for 20 h; stable up to 37°C for 24 h. **Infusion bag:** up to 80/10 mg/mL in a PVC bag with 500 mL NS or D5W at 21 mL/h; stable up to 37°C for 24 h.	Stable up to 72 h at 4°C	**Elastomeric:** PICC **Infusion bag:** PICC or Midline	Fractionated dosing: 4.5 g every 6 h. Flush line 2-3 times/day. Protect the infusion bag from sunlight.
Vancomycin	1.5 g in 100 mL NS over 120 min	15 mg/kg/day (adjust for weight and CrCl)	**Elastomeric pump:** up to 37 mg/mL in NS, 240 mL at 10 mL/h for 24 h or 12 mL/h for 20 h; stable up to 37°C for 48 h. **Infusion bag:** up to 5 mg/mL in a PVC bag with 500 mL NS at 21 mL/h; stable up to 37°C for 24 h.	Stable up to 72 h at 4°C	**Elastomeric:** PICC **Infusion bag:** PICC or midline	Fractionated dosing: 1 g every 12 h. Off-label continuous infusion is not required. Monitor serum creatinine every 72 h. Protect the infusion bag from sunlight.
Cefazolin	2 g in 100 mL NS or D5W	2 g every 8 h over 5 h by CI (adjust for CrCl) 6 g/day by CI or 3 g every 12 h (adjust for CrCl)	**Elastomeric pump:** up to 25 mg/mL in NS or D5W, 250 mL at 50 mL/h for 5 h; stable up to 37°C for 12 h. **Infusion bag:** up to 12 mg/mL in a PVC bag with 500 mL NS at 21 mL/h; stable up to 25°C for 24 h. Up to 20 mg/mL in 250 mL NS at 21 mL/h; stable up to 35°C for 12 h.	Stable up to 72 h at 4°C	**Elastomeric:** PICC **Infusion bag:** Midline or mini-midline	Fractionated dosing: 2 g every 8 h. Not stable for 24 h in elastomer. Requires bi- or tri-daily administration. Flush line 2-3 times/day. Protect the infusion bag from sunlight.
Oxacillin	3 g in 100 mL NS	12 g/day by CI (adjust for CrCl)	**Elastomeric pump:** up to 50 mg/mL in NS, 240 mL at 10 mL/h for 24 h or 12 mL/h for 20 h; stable up to 25°C for 24 h. **Infusion bag:** up to 25 mg/mL in NS, 500 mL at 21 mL/h for 24 h; stable up to 25°C for 24 h.	Stable up to 48 h at 4°C	**Elastomeric:** PICC **Infusion bag:** Midline	Fractionated dosing: 3 g every 6 h. Protect the infusion bag from sunlight.
Fosfomycin	6 g in 250 mL D5W	8-18 g/day by CI or 6 g every 8 h (adjust for CrCl)	**Elastomeric pump:** up to 75 mg/mL in 240 mL D5W at 10 mL/h for 24 h or 12 mL/h for 20 h; stable up to 30°C for 24 h. Alternative: 75 mg/mL in 250 mL D5W at 50 mL/h for 5 h; stable up to 30°C for 24 h. **Infusion bag:** up to 75 mg/mL in 500 mL D5W at 21 mL/h; stable up to 37°C for 24 h.	Stable up to 72 h at 4°C	**Elastomeric:** PICC or midline **Infusion bag:** PICC or midline	Monitor sodium and potassium. Fractionated dosing: 6 g every 8 h in D5W. Protect the infusion bag from sunlight.

Continued

Table 4 ***Continued.*** Antimicrobial agents: dosing, preparation, stability, venous access, and recommendations for OPAT[42].

Drug	Loading dose pre-OPAT	Dosage	Container – dilution, concentration and stability	Stability after reconstitution	Venous access	Recommendations
Ceftolozane/ Tazobactam	1.5 g in 100 mL NS	4.5 g/day by CI or 9 g/day by CI (pulmonary infections only; adjust for CrCl)	**Elastomeric pump:** 18-36 mg/mL in NS, 240 mL at 10 mL/h for 24 h or 12 mL/h for 20 h; stable up to 37°C for 24 h. Alternative: 6-12 mg/mL in 250 mL NS at 50 mL/h for 5 h; stable up to 37°C for 20-24 h. **Infusion bag:** up to 12-6 g/mL in 500 mL NS at 21 mL/h; stable up to 37°C for 24 h.	Stable up to 72 h at 4°C	**Elastomeric:** PICC **Infusion bag:** Midline or mini-midline	Fractionated dosing: 1.5 g every 8 h or 3 g every 8 h (pulmonary infections only). Flush line 2-3 times/day. Protect the infusion bag from sunlight.
Cefepime	2 g in 100 mL NS	2 g every 8 h over 5 h by CI (adjust for CrCl) 6 g/day by CI	**Elastomeric pump:** up to 12 mg/mL in sterile water, 250 mL at 50 mL/h for 5 h or 12 mL/h for 20 h; stable up to 37°C for 10-12 h. **Infusion bag:** up to 12 mg/mL in 500 mL NS at 21 mL/h for 24 h; stable up to 37°C for 24 h.	Stable up to 72 h at 4°C	**Elastomeric:** PICC **Infusion bag:** Midline	Fractionated dosing: 2 g every 8 h. Not stable for 24 h in elastomer. Requires bi- or tri-daily administration. Protect the infusion bag from sunlight.
Ceftazidime	2 g in 100 mL NS	2 g every 8 h (adjust for CrCl)	**Elastomeric pump:** up to 12 mg/mL in NS or D5W, 250 mL at 50 mL/h for 5 h; stable up to 37°C for 10-12 h. **Infusion bag:** 15 mg/mL in 250 mL NS or D5W at 150 mL/h for 1.5 h; stable up to 37°C for 10-12 h. 15 mg/mL in 500 mL NS or D5W by CI ≤17-18 h (28 mL/h).	Stable up to 24 h at 4°C	**Elastomeric:** Midline or mini-midline **Infusion bag:** Midline	Fractionated dosing: 2 g every 8 h. Monitor for yellow discoloration or sediment. Shield the infusion bag from light.
Ceftazidime/ Avibactam	2 g in 100 mL NS	2-0.5 g every 8 h (adjust for CrCl)	**Elastomeric pump:** 15 mg/mL in NS or D5W, 250 mL at 50 mL/h for 5 h; stable up to 37°C for 10-12 h. **Infusion bag:** 15 mg/mL in 250 mL NS or D5W at 150 mL/h for 1.5 h; stable up to 37°C for 10-12 h. 15 mg/mL in 500 mL NS or D5W by CI ≤17-18 h (28 mL/h).	Stable up to 24 h at 4°C	**Elastomeric:** PICC **Infusion bag:** PICC or midline	Fractionated dosing: 2.5 g every 8 h. Monitor for yellow discoloration or sediment. Protect the infusion bag from sunlight.
Ampicillin	3 g in 100 mL NS	4 g every 8 h over 5 h (adjust for CrCl) 12 g/day by CI	**Elastomeric pump:** up to 20 mg/mL in NS, 250 mL at 50 mL/h; stable up to 25°C for 6 h. **Infusion bag:** up to 20 mg/mL in 1,000 mL NS at 50 mL/h; stable up to 25°C for 24 h. Alternative: 20 mg/mL in 500 mL NS at 25 mL/h; stable up to 25°C for 24 h.	Stable up to 48 h at 4°C	**Elastomeric:** PICC **Infusion bag:** PICC or midline	Fractionated dosing: 3 g every 6 h. Not stable at higher temperatures. Protect the infusion bag from sunlight.
Cefiderocol	2 g in 100 mL NS	6 g/day by CI	**Infusion bag:** up to 12 mg/mL in PVC bag with 500 mL NS at 21 mL/h; stable up to 37°C for 24 h (optimal temperature 20-24°C).	Stable up to 48 h at 4°C	**Infusion bag:** PICC	Fractionated dosing: 2 g every 8 h. Protect the infusion bag from sunlight.

CI=Continuous Infusion; CrCl=Creatinine Clearance; D5W=5% Dextrose in Water; NS=Normal Saline; OPAT=Outpatient Parenteral Antimicrobial Therapy; PICC=Peripherally Inserted Central Catheter; PVC=Polyvinyl Chloride.

THERAPEUTIC DRUG MONITORING IN OPAT

Therapeutic drug monitoring (TDM) offers several clinically relevant advantages in ensuring the correct antimicrobial dose. Classically, TDM plays a key role in improving the safety profile of antimicrobial treatment, particularly with aminoglycosides and glycopeptides. However, TDM in OPAT could have an additional advantage by allowing assessment of adequate drug exposure at the individual patient level, enabling dose optimization to increase the likelihood of achieving predefined pharmacokinetic/pharmacodynamic (PK/PD) targets, which are necessary for maximizing killing or inhibition of bacterial growth.

The Infectious Diseases Society of America (IDSA) recommends TDM as part of OPAT management to reduce the risk of rehospitalization and enable early identification of efficacy or toxicity issues[1]. These principles are supported by more recent data[1,52,53] showing that TDM is already being implemented in OPAT programs for several antibiotics, with essential benefits for both efficacy and safety. For aminoglycosides and vancomycin, TDM remains essential to limit toxicity and reduce the risk of readmission due to treatment-related adverse events, as supported by studies showing reductions in adverse events when appropriate monitoring strategies are used[1,52,53]. According to IDSA recommendations, the type and frequency of monitoring should be individualized based on the antimicrobial agent used and the expected duration of therapy. For most antibiotics, weekly monitoring is suggested, whereas shorter treatment courses may not require routine laboratory assessment[1].

In the case of beta-lactams in OPAT, TDM has enabled optimization of plasma exposure and real-time dose adjustment, ensuring therapeutic concentrations, improving clinical outcomes and bacterial clearance, reducing the risk of microbiological breakthrough and antibiotic resistance[54,55].

The literature supports the view that TDM is particularly valuable in patients with high PK variability, comorbidities, the elderly, hepatic and renal impairment, or an increased risk of toxicity, where the variability in terms of drug exposure could be significant[56,57].

DISCUSSION

OPAT represents a valid model of care for patients requiring prolonged IV antimicrobial therapy, enabling a safe transition from inpatient to outpatient settings without compromising clinical outcomes.

Appropriately and safely applying OPAT requires shared operational instructions and a structure with other operational units involved. Appropriate selection of the patient and venous access, tailored to the physicochemical properties of antimicrobial agents and infusion modalities, is essential to minimize the risk of side effects or unfavorable outcomes. Continuous infusion through elastomeric pumps offers PK/PD advantages and logistical feasibility in the outpatient setting. In this context, TDM could play a crucial role not only in preventing toxicity but also in optimizing drug exposure and achieving therapeutic targets, as demonstrated by the high rate of dose adjustments observed in our real-life cohort[6,57].

OPAT delivers substantial organizational and economic benefits, with marked reductions in hospital bed stays and associated costs[58]. These advantages, combined with improved patient quality of life, make OPAT an essential strategy in modern infectious disease management, where prolonged therapy may be necessary. Moreover, OPAT represents a valid alternative for multi-drug resistant organisms (MDRO) management, particularly when few oral therapeutic options are available, as in some bacterial and fungal infections[59,60].

CONCLUSIONS

Future efforts should focus on expanding access to OPAT, harmonizing protocols across healthcare systems, integrating digital monitoring tools, and generating high-quality prospective data to further refine patient selection, monitoring strategies, and outcome assessment in this rapidly evolving field.

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L.M. and N.G. conceived the study, designed the manuscript structure, and wrote the article. S.P., S.M., and P.C. critically revised the manuscript for important intellectual content and supervised the scientific development of the work. F.P., A.S., C.B., V.S., P.B., N.P., E.S., D.G., J.Z., M.P., S.B., S.B., L.B., and E.T. contributed to the study's conceptualization and literature review. All authors reviewed and approved the final version of the manuscript.

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No artificial intelligence was used in the preparation of this manuscript.

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