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Chemotherapy-Related Toxicities and Clinical Management: An Article Review

Maria Julia Frauches Rocha[1*], Ian Caldeira Ruppen[1], Maria Tayna Gesualdo[1], Maria Eduarda Galhardo Carvalho Fernandes[1], Priscila De Oliveira Barros[1], André Cesar Leandro[1], Emily Eduarda Hellmann[1], Amanda Maia Porcinelli[1], Larissa da Rosa Piccoli[1], Guilherme Gasparotto[1], Tauane Cano Barreto[2], Camilla Antunes Zanini[3], Geovani Almeida Gois[4], Laura Vieira Reis[1] and Heloisa Belinati Pereira Perez[1]

[1]Centro Universitario Inga Uninga, Maringa, PR, Brazil

[2]Hospital Memorial Uninga HMU, Maringa, PR, Brazil

[3]Faculdade Morgana Potrich, Mineiros, GO, Brazil

[4]Universidade Federal do Maranhao, Brazil

ABSTRACT

Chemotherapy-induced toxicities remain one of the greatest obstacles to maintaining the ideal therapeutic intensity in cancer treatment. Despite advances in targeted therapies and immunotherapies, most cytotoxic regimens still have a considerable safety burden, resulting in delays, dose reductions, and early discontinuation. The most prevalent adverse effects include myelosuppression, nausea and vomiting, peripheral neuropathy, mucositis, diarrhea, cardiotoxicity, and dermatologic manifestations. These events impair quality of life, increase hospitalization risk, and raise healthcare costs, making the development of evidence-based prevention and management strategies imperative. This review describes the principal toxicities associated with traditional chemotherapeutic agents, discussing their underlying pathophysiology, risk factors, and clinical complications. Preventive measures, supportive therapies, and multidisciplinary approaches capable of reducing symptom severity and enabling treatment continuity. such as colony-stimulating factors, next-generation antiemetics, cardioprotective agents, mucosal-care protocols, and telemonitoring programs are presented. Emerging trends, including the use of predictive toxicity biomarkers and real-time digital symptom-assessment tools, are also explored. We conclude that dose individualization, close follow-up, and patient education are fundamental to minimize complications, maintain therapeutic adherence, and optimize oncologic outcomes. Systematic adoption of these practices, allied to technological innovation, represents a promising path to transform oncologic care, ensuring greater safety and well-being for patients at all treatment stages. This review reinforces the central role of the multiprofessional team in the early recognition of toxicity signs, implementation of standardized interventions, and timely adjustment of therapeutic plans, ultimately improving clinical outcomes and lowering treatment-related mortality. Thus, integration among research, clinical care, and technology constitutes a strategic pillar for sustainable advances in modern oncology.

***Corresponding author**

Ian Caldeira Ruppen, Centro Universitaario Inga Uninga, Maringa, Parana, Brazil.

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Introduction

Since the mid-20th century, chemotherapy has remained a cornerstone of cancer treatment used alone or as adjuvant or neoadjuvant therapy to surgery and radiotherapy. Its fundamental principle is the ability of cytotoxic agents to disrupt cell division, leading to tumor-cell death or senescence. However, action on rapidly renewing tissues such as bone marrow, gastrointestinal epithelium, and hair follicles explains the wide array of adverse effects reported in clinical practice. Biotechnological advances have led to the emergence of targeted drugs and immune therapeutics that broaden the spectrum of tumor control with lower systemic toxicity; nevertheless, regimens that include classic agentes such as platinums, taxanes, anthracyclines, and antimetabolites remain indispensable for managing solid and hematologic tumors at various stages. Epidemiologic reports estimate that 65–80 % of cancer patients will receive some chemotherapy regimen during the disease course, and dose intensity is a direct determinant of overall and progression-free survival. Therefore, preventing and mitigating toxicities is fundamental to ensure treatment continuity and effectiveness.

From a pathophysiologic standpoint, toxicities can be classified as acute, subacute, or late. Acute reactions include nausea, vomiting, hypersensitivity reactions, and tumor-lysis syndrome, whereas late manifestations such as heart failure or persistent neuropathy may arise months or years after therapy ends. Drug-related factors (cumulative dose, formulation, elimination route), tumor factors (biology and proliferation rate), and host factors (age, functional status, comorbidities, and genetic polymorphisms) modulate

individual susceptibility. Advances in toxicogenomics have identified gene variants that predispose to severe adverse events for example, the DPYD*2A allele in fluoropyrimidine-induced toxicity allowing pre-treatment dose adjustments and a reduction of up to 30 % in associated hospitalizations. The current literature highlights three central intervention axes: prophylaxis, early monitoring, and treatment of complications. Support-care protocols recommended by entities such as the National Comprehensive Cancer Network (NCCN) provide evidence-based algorithms for prophylaxis of febrile neutropenia, risk stratification of nausea and vomiting, and cardiotoxicity surveillance. In parallel, digital health Technologies including mobile apps and teleconsultation have been used to collect patient-reported outcomes (PROs), enabling real-time interventions and reducing emergency-department visits. Randomized trials show a 20 % reduction in grade 3-4 outcomes among users of these tools compared with usual care. Gaps nevertheless remain. Chemotherapy-induced peripheral neuropathy (CIPN), primarily associated with taxanes, vincristine, and oxaliplatin, lacks consistent preventive methods; phase III studies with antioxidants and neuroprotective agents have yet to yield routinely applicable results. Similarly, anthracycline-related cardiotoxicity remains a relevant obstacle, especially in populations with pre-existing cardiovascular risk factors. Strategies such as dose fractionation, liposomal encapsulation, and dexrazoxane use show benefit but remain underused due to cost or availability barriers. Hence, understanding the complexity of chemotherapy toxicities and having adequate tools for their prevention and management are prerequisites for contemporary oncology practice.

Objectives

This article aims to review the main toxicities associated with chemotherapy, highlight the most widely used management strategies, and discuss perspectives for minimizing these adverse effects. It also addresses the importance of multidisciplinary, integrated care involving oncologists, nurses, pharmacists, nutritionists, psychologists, and other health professionals in the pursuit of safer and more effective therapeutic outcomes.

Materials and Methods

A literature review was conducted using the PubMed, SciELO, Google Scholar, and ScienceDirect databases.

Discussion

Integrated analysis of the latest data identifies patterns and gaps in controlling chemotherapy toxicities. Regarding hematologic complications, meta-analyses indicate that prophylactic use of granulocyte colony-stimulating factors (G-CSF) reduces febrile-neutropenia incidence by 50 % and related mortality by 20 %. Cost-effectiveness studies show that, when avoided hospitalization expenses are considered, investing in G-CSF becomes advantageous in regimens with ≥10 % neutropenia risk. Gastrointestinal toxicities chiefly nausea, vomiting, and mucositis have been greatly transformed by introducing 5-HT3 and NK-1 receptor antagonists and synthetic cannabinoids. Randomized trials show complete control of acute nausea in up to 80 % of patients with triple-therapy protocols, compared with 40 % achieved by traditional double combinations. Still, full adherence to guidelines remains variable.

Oral mucositis poses an additional challenge in high-dose regimens; low-level laser therapy is one of the few interventions with level-1 evidence for prevention and treatment, reducing re-epithelialization time by about five days. Concerning neurotoxicity, CIPN is singled out as a primary source of long-term sequelae in cancer survivors. Cohort studies record that up to 40 % of patients report disabling neuropathic symptoms two years after treatment ends, affecting return to work and daily activities. Interventions such as cryotherapy, limb compression during taxane infusion, and duloxetine for neuropathic pain offer modest benefit, underscoring the need for translational research to elucidate molecular mechanisms and identify specific neuroprotective targets.

Cardiotoxicity is of growing concern owing to population aging and the consequent higher prevalence of cardiovascular comorbidities. Observational studies indicate that up to 15 % of survivors treated with anthracyclines develop cardiomyopathy within ten years, with reduced ejection fraction an independent mortality predictor. Contrast-enhanced echocardiographic parameters and serum markers such as troponin I and brain natriuretic peptide (BNP) show early sensitivity to subclinical dysfunction and should be incorporated into high-risk surveillance protocols. Dose fractionation and liposomal formulations significantly reduce grade 3-4 cardiac events, although their added cost still limits widespread use.

Dermatotoxicities, while less life-threatening, affect self-esteem and adherence. Strategies based on intensive skin hydration and moderate-potency topical corticosteroids lowered treatment interruption due to rash by 30 % in EGFR-inhibitor protocols. Educational programs with practical demonstrations of skin-care routines achieved >80 % satisfaction among participants.

Finally, the incorporation of digital technologies and artificial intelligence emerges as a promising frontier. Predictive models fed with clinical and genomic data now achieve areas under the curve (AUC) >0.80 for grade-4 neutropenia prediction, enabling pre-treatment dose adjustments. Mobile-notification systems and telemonitoring reduced unplanned hospitalizations by 18 % in a phase-III multicenter study. Despite these results, barriers related to system interoperability, data privacy, and patient digital literacy require strategic approaches. Findings highlight the urgency of public policies facilitating access to essential supportive therapies and continuous professional-education programs. Integrating translational research, evidence-based clinical practice, and technological innovation will underpin patient centered oncology that balances efficacy and safety [1-15].

Conclusion

Mitigating chemotherapy-associated toxicities is a strategic axis for optimizing oncologic outcomes and fostering patient centered care. This review demonstrates consistent progress in understanding the pathophysiology of adverse events and in incorporating prophylactic and therapeutic interventions that translate into improved survival and quality of life. Supportive agents such as colony-stimulating factors, next-generation antiemetics, and cardioprotective drugs constitute a consolidated standard of care. However, socioeconomic disparities limit access, reinforcing the need for public policies that ensure universal and equitable coverage. Systematic monitoring particularly via highly sensitive clinical, laboratory, and imaging markers-proved fundamental for early detection of hematologic, cardiac, and neurologic dysfunction, enabling timely interventions. In this context, digital telemonitoring technologies and patient-reported-outcome platforms have proven effective in reducing unplanned hospitalizations and maintaining relative dose intensity. Despite enthusiasm for care digitalization, infrastructure and health-literacy barriers still restrict broad use, especially in remote regions.

Treatment individualization is emerging as an irreversible trend. Mapping genetic polymorphisms related to metabolism and DNA repair, combined with AI-based predictive algorithms, offers a unique opportunity to adjust doses and select less-toxic agents without reducing antineoplastic efficacy. Phase II and III trials already validate the use of pharmacogenomic panels in practice and demonstrate considerable savings in hospitalization costs for severe adverse-event management. Integrating molecular testing into routine care, however, depends on clear regulatory frameworks and adequate reimbursement by health systems. Empowerment of the multiprofessional team is also crucial. Continuing-education programs and evidence-based institutional protocols significantly reduced care variability and increased adherence to international recommendations. Active participation of nurses, clinical pharmacists, nutritionists, and physiotherapists enables holistic patient assessment, identification of modifiable risk factors, and implementation of personalized preventive measures, contributing to humanized care and more confident therapeutic relationships.

Although targeted therapies and immunotherapies present distinct toxicity profiles, they are not free from significant complications. Experience with immune-checkpoint inhibitors and intracellular-pathway modulators indicates new damage modalities, such as autoimmune colitis and endocrinopathies, requiring specific surveillance and management. Adapting supportive efforts to the particularities of emerging therapeutic platforms will be decisive for their long-term success. In sum, reducing the burden of chemotherapy toxicities presupposes integration among innovation, education, and access policies. By investing in translational research, strengthening universal support programs, and implementing digital monitoring tools, health systems will be able to deliver increasingly effective and safe oncologic treatments.

The collective commitment of professionals, managers, and policymakers will be decisive for translating such advances into tangible benefits, ensuring that life prolongation is accompanied by well-being and dignity for all people facing cancer. Future perspectives include expanding controlled trials, developing targeted-delivery nanosystems to minimize systemic exposure, and incorporating quality indicators based on patient experience. Precision oncology, supported by big-data analytics and machine learning, may evolve toward real-time adaptive models. Such advances will require synergy among research centers, the pharmaceutical industry, and regulatory agencies. Simple interventions such as self-care education and psychological support will continue to alleviate suffering and improve adherence, reinforcing that technological innovation must advance hand in hand with the appreciation of the human dimensions of care.

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