



# Granulocyte Transfusion Therapy: Institutional Experience of Benefit in Cancer Patients with Prolonged Neutropenic Sepsis—A Retrospective Study

Shiv Prasad Shrivastava<sup>1</sup> Aditya Elhence<sup>1</sup> Pruthi Jinwala<sup>1</sup> Shashank Bansal<sup>1</sup> Prakash Chitalkar<sup>1</sup>  
Shweta Bhatnagar<sup>2</sup> Rajesh Patidar<sup>1</sup> Vikas Asati<sup>1</sup> Pradeep Kumar Reddy<sup>3</sup>

<sup>1</sup> Department of Medical Oncology, Sri Aurobindo Institute of Medical Sciences, Indore, Madhya Pradesh, India

<sup>2</sup> Department of Radiology, Kokilaben Dhirubhai Ambani Hospital, Indore

<sup>3</sup> Department of Medical Oncology, Sri Aurobindo Institute of Medical Sciences, Indore, Madhya Pradesh

Address for correspondence Shiv Prasad Shrivastava, Department of Medical Oncology, Sri Aurobindo Institute of Medical Sciences, Indore, Madhya Pradesh 45355, India (e-mail: drsp2001@yahoo.com).

Ind J Med Paediatr Oncol 2022;43:507–512.

## Abstract

**Introduction** Patients undergoing intensive chemotherapy for hematological malignancy and stem cell transplantation are at increased risk of neutropenia.

Neutropenia is among the frequent side effects of intensive treatments, and when absolute neutrophil count (ANC) falls  $< 500/\mu\text{L}$ , the risk of microbial and fungal infection increases significantly.

As neutropenia is the main cause of these infections, transfusion of granulocyte immediately as a replacement is a life-saving therapeutic option to support these patients by restoring neutrophil counts and aiding in the resolution of infection.

**Objective** The present study is a retrospective single institutional analysis of granulocyte transfusion therapy in children and young adults with cancer who received treatment with GT during prolonged and profound life threatening neutropenia.

**Materials and Methods** This study was a retrospective analysis of 66 granulocyte transfusions in 36 patients of hematological and solid malignancy with severe and prolonged neutropenia in the department of Medical Oncology, Sri Aurobindo Institute of Medical Sciences Indore, between September 2019 and March 2022.

Donors were either patients' relatives or voluntary donors without comorbidities.

All granulocyte concentrates were collected by centrifugation leukapheresis and irradiated with 2500 centigray and immediately transfused in full, to the patient over 60 to 120 minutes with appropriate premedication.

**Results** A total of 36 patients (M:F, 19:17) with a median age of 16 years (2–43) received 66 granulocyte transfusions. The diagnosis of patients included acute myelogenous leukemia ( $n = 17$ ), B cell acute lymphoblastic leukemia ( $n = 10$ ), non-Hodgkin lymphoma ( $n = 3$ ), Ewing's sarcoma ( $n = 2$ ), neuroblastoma ( $n = 1$ ), malignant melanoma ( $n = 1$ ), aplastic anemia ( $n = 1$ ), osteosarcoma ( $n = 1$ ). All had severe neutropenia with absolute neutrophil count  $< 0.5 \times 10^9/\text{L}$ . The median duration of

## Keywords

- cancer
- granulocyte transfusion
- neutropenia

DOI <https://doi.org/10.1055/s-0042-1757730>.  
ISSN 0971-5851.

© 2022. The Author(s).

This is an open access article published by Thieme under the terms of the Creative Commons Attribution License, permitting unrestricted use, distribution, and reproduction so long as the original work is properly cited. (<https://creativecommons.org/licenses/by/4.0/>)

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

severe neutropenia was 16 days. Patients received a median cell dose of granulocytes  $2.9 \times 10^{10}/L$ . A favorable response was seen in 28 (78%) patients, whereas an unfavorable response was seen in 8 patients (23%).

**Conclusion** A granulocyte therapy was effective in many critically sick patients with prolonged and profound neutropenia. Granulocyte transfusions may be more beneficial in selected patients where it provides more time to overcome refractory infections with broad-spectrum antibiotics. Granulocyte transfusion are at best a “bridge” that gives time to marrow recovery. The challenges to using GT are clinical, finding patients who may get benefitted, and logistical, selection of donors and harvest technique. Randomized trials with large numbers of patients are required to prepare guidelines for granulocyte use.

## Introduction

Patients received aggressive chemotherapy for hematological malignancy and stem cell transplantation are at higher risk of neutropenia.

Bacteria, viruses, and fungi are the main complication-producing agents in most patients with profound and prolonged treatment related to neutropenia despite newer antimicrobials and antifungals.

Neutropenia is among the common side effects of intensive treatments, and when absolute neutrophil count (ANC) falls  $< 500/\mu L$  (Grade IV neutropenia), the risk of microbial and fungal infection increases significantly.

As of now, bacterial and fungal infections such as *Aspergillus* and *Fusarium* in patients with neutropenia have increased and eventually morbidity and mortality rates.<sup>1</sup>

Improvement in the overall general and intensified care in oncology units with the use of newer and effective broad-spectrum antimicrobial and antifungal drugs resulted in significantly better survival.

Irrational prescription of higher antimicrobial and antifungal without checking the sensitivity has led to the development of resistance to these drugs across India and due to this, dreaded infections do not respond as needed.<sup>2</sup>

As neutropenia is the main cause of these infections, transfusion of granulocyte immediately as a replacement is a life-saving therapeutic option to support these patients by restoring neutrophil counts and aiding in the resolution of infection.

Granulocyte transfusion (GT) therapy was conceptualized in the 1960s, and many studies have shown that it is a useful supportive therapy in the case of neutropenia.<sup>3-6</sup>

Granulocytes transfusion used for prophylactic therapy with antimicrobials in patients who received intensive chemotherapy and developed severe neutropenia.<sup>5,7-9</sup>

The present study was a retrospective single institutional analysis of granulocyte transfusion therapy in children and young adults with cancer who received treatment with GT during prolonged and profound life-threatening neutropenia.

## Materials and Methods

This study was a retrospective analysis of all patients who received granulocyte transfusions between Septem-

ber 2019 and March 2022 in the Department of Medical Oncology, Sri Aurobindo Institute of Medical Sciences Indore, India.

Granulocyte transfusion (GT) therapy was prescribed in all patients with (1) absolute neutrophil count (ANC)  $< 500$  cells/ $\mu L$ , (2) evidence of bacterial or fungal infection (i.e., clinical presentation, positive cultures, biopsy, or radiological evidence), and (3) lack of response to the recently introduced antimicrobials for 48 hours.

After granulocyte transfusions, we monitored ANC until recovery to  $> 500/\mu L$ . No fever in more than 48 hours, symptomatic relief, and negative cultures with radiological absence of infection were considered as a response. A tandem GT was given to nonresponders.

Donors were either patients' relatives or voluntary donors without comorbidities and blood group incompatibility with the patient. After informed consent, screened donors received subcutaneous colony-stimulating growth factor (G-CSF)  $10 \mu g/kg$  with injection dexamethasone 8 mg and were taken for granulocyte harvest after 10 to 12 hours via peripheral vascular access by centrifugation leukapheresis using the Fresenius COM TEC system. All harvest volume was irradiation with 2500 centigray and transfused to the patient over 60 to 120 minutes after appropriate premedication.

## Statistical Analysis

The data were collected in an Excel sheet and statistical analysis was performed using SPSS, version 23.0. Considering the nature of the study, no formal sample size was employed. Categorical variables are presented as numbers and percentages, whereas continuous variables are expressed as median and range.

## Ethics

This study was conducted in accordance with the ethical principles that are consistent with the Declaration of Helsinki, the International Conference on Harmonization of Good Clinical Practices, and the applicable legislation on non-interventional studies. The study protocol was approved by the institutional ethics committee (IEC no. SAIMS/IEC/2022/11). Informed consent was waived due to the retrospective nature of the study.

**Table 1** Clinical characteristics of patients received granulocyte transfusion therapy

Characteristics of patients	
Number of patients	36
Age (y), median. ange	16 (2–43)
<b>Sex</b>	
Male	19 (53%)
Female	17 (47%)
<b>Underlying disease, n</b>	
Acute myelogenous leukemia	17
B-cell acute lymphoblastic leukemia	10
Non-Hodgkin lymphoma	3
Ewing's sarcoma	2
Neuroblastoma	1
Aplastic anemia	1
Malignant melanoma	1
Osteosarcoma	1
Severe neutropenia ( $ANC < 0.5 \times 10^9/\mu L$ ), n	36/36
Duration of neutropenia, days, median (range)	16 (7–24)
G-CSF treatment used before granulocyte therapy	36/36
Systemic treatment with antimicrobial before granulocyte, n	36/36
Systemic treatment with antifungal before granulocyte, n	36/36
Granulocyte cell dose received, median (range), n	$2.9 \times 10^{10}/L$ ( $2.0 \times 10^{10}/L$ – $4.8 \times 10^{10}/L$ )
Days to neutrophil recovery, median (range) n	9 (3–19)
Adverse effect	1/66

## Results

A total of 36 patients (M:F, 19:17) with a median age of 16 years (2–43) received 66 granulocyte transfusions. The disease-wise distribution were acute myelogenous leukemia ( $n = 17$ ), B cell acute lymphoblastic leukemia ( $n = 10$ ), non-Hodgkin lymphoma ( $n = 3$ ), Ewing's sarcoma ( $n = 2$ ), neuroblastoma ( $n = 1$ ), malignant melanoma ( $n = 1$ ), aplastic anemia ( $n = 1$ ), osteosarcoma ( $n = 1$ ). All had severe neutropenia with absolute neutrophil count  $< 0.5 \times 10^9/L$ . The median duration of severe neutropenia was 16 days (7–24 days). Granulocyte transfusion therapy was prescribed in patients because of persistent neutropenic fever with pneumonia ( $n = 18$ ), soft tissue infections ( $n = 8$ ), neutropenic enterocolitis ( $n = 7$ ), and deterioration in condition despite granulocyte colony-stimulating factor (G-CSF), broad-spectrum antimicrobial therapy and antifungal therapy. GT was given until  $ANC > 0.5 \times 10^9/L$ . Patients received a median cell dose of granulocytes  $2.9 \times 10^{10}/L$  (range  $2.0 \times 10^{10}/L$ – $4.8 \times 10^{10}/L$ ). A favorable response was seen in 28 (78%) patients in terms of early recovery from neutropenia and resolution of infections. The median time to neutrophil count recovery was 9 days (3–19 days), whereas 8 patients (23%) showed poor response, who succumbed to infections. GT were tolerated by all patients except for transfusion-associated acute lung injury (TRALI) in one patient who succumbed despite all

intensive care in the hospital. The clinical characteristics of patients who received granulocyte transfusion therapy are shown in ►Table 1.

In all 36 patients, post chemotherapy neutropenia was developed, including one post autologous stem cell transplantation. Microbiologically documented infections were seen in 35 patients (97%). Nine patients developed invasive fungal infections and 29 bacterial infections. The infection profile and culture positivity are shown in ►Table 2.

All patients received ongoing antimicrobial and systemic antifungal therapy before and during GT treatment. All 66 donors tolerated apheresis well with no adverse effects.

**Table 2** Infection profile/cultures in patients

Infection agent	Number of positive cultures
<i>Acinetobacter</i>	1
<i>Klebsiella</i>	17
<i>Pseudomonas</i>	7
<i>Escherichia coli</i>	1
MRSA	3
<i>Candida</i> , mucormycosis	9
Total	38

Abbreviation: MRSA, methicillin-resistant *Staphylococcus aureus*.

**Table 3** Granulocyte donor characteristics

Donor characteristic	Number	Median
Number of donors	66	
Donor pre leukapheresis WBC counts, median (range)		$3.17 \times 10^{10}/L$ ( $2.19 \times 10^{10}/L$ – $4.49 \times 10^{10}/L$ )
Adverse effects in donor	0/66	

Abbreviation: WBC, white blood cell.

Median pre leukapheresis WBC counts were  $3.17 \times 10^{10}/L$  ( $2.19 \times 10^{10}/L$ – $4.49 \times 10^{10}/L$ ). Granulocyte donor characteristics are shown in ►Table 3.

## Discussion

Transfusion of granulocytes is an efficacious therapy to fight severe life-threatening bacterial and fungal infections in patients with neutropenia.

Donor injection of colony-stimulating growth factor (G-CSF) with dexamethasone mobilizes granulocytes into the peripheral blood from the marrow, increasing the granulocyte count in 2 to 12 hours.<sup>10</sup> Collection of up to 5 to  $10 \times 10^{10}/L$  granulocytes in one session became possible.<sup>11–13</sup>

Large granulocyte doses raise ANC in patients with neutropenia.<sup>14</sup>

After G-CSF administration, increased neutrophils accumulate at the location of inflammation or infection and help in getting rid of infection.<sup>15</sup>

Lee et al<sup>16</sup> reported G-CSF with dexamethasone was better as compared with dexamethasone alone in mobilizing granulocyte from the bone marrow to peripheral blood to increase harvest volume.

Drewnian et al<sup>17</sup> described that due to upregulation of Toll-like receptors after G-CSF and dexamethasone, donor cells secrete IL-8, which helps in controlling microbial infections.

Progressive infection in neutropenic patients not responding to antimicrobial and antifungal within 48 hours, granulocyte transfusions have been recommended to raise ANC promptly to faster recovery. The therapeutic dose of granulocyte and its efficacy is still controversial. Next,  $2$ – $3 \times 10^{10}/kg$  is the minimum granulocyte dose needed to increase ANC and transfusions are given until the absolute neutrophil counts become more than  $500/\mu L$  and/or until the resolution of infection.<sup>18,19</sup>

The Resolving Infection in Neutropenia with Granulocytes (RING) trial<sup>20</sup> concluded that patients who received granulocytes dose  $> 0.6 \times 10^9/kg$  reported improved survival at 42 days as compared with patients who received a dose  $< 0.6 \times 10^9/kg$ . The median granulocyte dose received by our patients was  $2.9 \times 10^{10}/kg$  equivalent to the above studies.

Nikolajeva et al<sup>21</sup> reported a decrease infection-associated death in patients who received a median cell count of  $1.5$  to  $3.0 \times 10^8$  granulocytes/kg.

Garg et al<sup>22</sup> reported that an increase in the total leucocyte count 6 hours after a high dose of  $10 \times 10^8/kg$  of GT did not affect the survival at 30 days.

Grigull et al<sup>7</sup> and Seidel et al<sup>23</sup> reported that granulocyte transfusion is feasible and safe in controlling the treatment of refractory bacterial infection and decreasing mortality.

Atay et al<sup>24</sup> analyzed 35 pediatric patients who had 111 granulocyte transfusions in view of the increased risk of neutropenia, reported 82.4% infection-related survival of 82.4% and overall survival (OS) of 77% at day 30.

Garg et al<sup>22</sup> and Zhou et al<sup>25</sup> showed that granulocyte therapy is useful in managing severe infections due to neutropenia in patients with hematological disorders or undergoing hematopoietic stem cell transplantation (HSCT) along with more benefits in patients having respiratory system infections (80%) in comparison to bloodstream infection group (58.3%) and skin or mucous infection group (20%).

In accordance with other studies, our study showed that 28/36 (78%) patients responded to granulocyte transfusions, recovered from life-threatening infections; however, 15/28 (54%) patients died on account of the progression of their disease. Also, 8/36 (22%) of our patients showed a transient response but eventually died; only one death was due to a post GT pulmonary event.

Lee et al reported benefits of GT in gram-negative bacterial and resistant infections as compared with infections with gram-positive organisms. The difference in response is possibly due to an early uptake with persistent retention of neutrophils at gram-negative infection sites, whereas there is no increase in neutrophil uptake at gram positive infection sites.<sup>16</sup>

The common etiology for sepsis was gram-negative organisms at our institute.

The effectiveness of granulocyte transfusions is determined by their starting time. Early transfusion during sepsis increases the chances of survival by preventing the onset of multiorgan damage. Sachs et al showed a 92.6% overall response to early GT and a better toxicity profile. Uppuluri et al<sup>2</sup> reported early administration of granulocyte within 48 hours of a septic episode resulting in significant improvement in the overall survival (41% to 54%).

Garg et al<sup>22</sup> reported that GT within 7 days of neutropenic sepsis leads to significantly higher overall survival in patients ( $p = 0.01$ ).

The modest survival in our study is probably due to a delay in starting GT, difficulty in finding donors, and lesser affordability.

Tandem granulocyte transfusions in neutropenic patients are effective. Seidel et al<sup>23</sup> reported repeated transfusion of granulocytes for 5 days with a minimum of  $3 \times 10^8/kg$  neutrophils/concentrate, stabilized ANC, reduced the neutropenic duration, and increased infection control.

In our study, all 8 patients who had received a single transfusion of granulocytes died.

Price et al<sup>14</sup> and Adkins et al<sup>26</sup> reported GT was well tolerated and the incidence of serious adverse events in recipients was uncommon. Chills and rigor were frequent side effects in recipients of granulocytes.

Other reported adverse events of GT are transfusion-associated acute lung injury (TRALI), transfusion-associated circulatory overload (TACO), transfusion-associated dyspnea, hypotension, post-transfusion purpura, transfusion-transmitted infection, and risk of alloimmunization. At our center, all granulocyte collections were irradiated before transfusion to decrease the chance of alloimmunization.

## Conclusion

A granulocyte therapy was effective in many critically sick patients with prolonged and profound neutropenia. Granulocyte transfusions may be more beneficial in selected patients where it provides more time to overcome refractory infections to broad-spectrum antibiotics. Granulocyte transfusion are at best a "bridge" that gives time to marrow recovery. The challenges to using GT are clinical, finding patients who may get benefitted, and logistical; selection of donors and harvest technique. Randomized trials with large numbers of patients are required to prepare guidelines for granulocyte use.

### Funding

None.

### Conflict of Interest

None declared.

## References

- Marr KA, Carter RA, Crippa F, Wald A, Corey L. Epidemiology and outcome of mould infections in hematopoietic stem cell transplant recipients. *Clin Infect Dis* 2002;34(07):909–917
- Uppuluri R, Ramachandrakurup S, Vaidhyanathan L, Kandath S, Subburaj D, Raj R. Changing trends in the use of granulocyte transfusions in neutropenic children with sepsis in India. *Indian J Hematol Blood Transfus* 2017;33(02):207–210. Doi: 10.1007/s12288-016-0727-2
- Freireich EJ, Levin RH, Whang J, Carbone PP, Bronson W, Morse EE. The function and fate of transfused leukocytes from donors with chronic myelocytic leukemia in leukopenic recipients. *Ann N Y Acad Sci* 1964;113:1081–1089
- Herzig RH, Herzig GP, Graw RG Jr, Bull MI, Ray KK. Successful granulocyte transfusion therapy for gram-negative septicemia. A prospectively randomized controlled study. *N Engl J Med* 1977;296(13):701–705. Doi: 10.1056/NEJM197703312961301
- Sachs UJ, Reiter A, Walter T, Bein G, Woessmann W. Safety and efficacy of therapeutic early onset granulocyte transfusions in pediatric patients with neutropenia and severe infections. *Transfusion* 2006;46(11):1909–1914. Doi: 10.1111/j.1537-2995.2006.00996.x
- Kikuta A, Ohto H, Nemoto K, et al. Therapeutic transfusions of granulocytes collected by simple bag method for children with cancer and neutropenic infections: results of a single-centre pilot study. *Vox Sang* 2006;91(01):70–76. Doi: 10.1111/j.1423-0410.2006.00776.x
- Grigull L, Pulver N, Goudeva L, et al. G-CSF mobilised granulocyte transfusions in 32 paediatric patients with neutropenic sepsis. *Support Care Cancer* 2006;14(09):910–916
- Oza A, Hallemeier C, Goodnough L, et al. Granulocyte-colony-stimulating factor-mobilized prophylactic granulocyte transfusions given after allogeneic peripheral blood progenitor cell transplantation result in a modest reduction of febrile days and intravenous antibiotic usage. *Transfusion* 2006;46(01):14–23
- Cesaro S, Chinello P, De Silvestro G, et al. Granulocyte transfusions from G-CSF-stimulated donors for the treatment of severe infections in neutropenic pediatric patients with onco-hematological diseases. *Support Care Cancer* 2003;11(02):101–106
- Price TH, Chatta GS, Dale DC. Effect of recombinant granulocyte colony-stimulating factor on neutrophil kinetics in normal young and elderly humans. *Blood* 1996;88(01):335–340
- Liles WC, Huang JE, Llewellyn C, SenGupta D, Price TH, Dale DC. A comparative trial of granulocyte-colony-stimulating factor and dexamethasone, separately and in combination, for the mobilization of neutrophils in the peripheral blood of normal volunteers. *Transfusion* 1997;37(02):182–187
- Stroncek DF, Yau YY, Oblitas J, Leitman SF. Administration of G-CSF plus dexamethasone produces greater granulocyte concentrate yields while causing no more donor toxicity than G-CSF alone. *Transfusion* 2001;41(08):1037–1044
- Dale DC, Liles WC, Llewellyn C, Rodger E, Price TH. Neutrophil transfusions: kinetics and functions of neutrophils mobilized with granulocyte-colony-stimulating factor and dexamethasone. *Transfusion* 1998;38(08):713–721
- Price TH, Bowden RA, Boeckh M, et al. Phase I/II trial of neutrophil transfusions from donors stimulated with G-CSF and dexamethasone for treatment of patients with infections in hematopoietic stem cell transplantation. *Blood* 2000;95(11):3302–3309
- Bishton M, Chopra R. The role of granulocyte transfusions in neutropenic patients. *Br J Haematol* 2004;127(05):501–508. Doi: 10.1111/j.1365-2141.2004.05221.x
- Lee JJ, Chung IJ, Park MR, et al. Clinical efficacy of granulocyte transfusion therapy in patients with neutropenia-related infections. *Leukemia* 2001;15(02):203–207. Doi: 10.1038/sj.leu.2402007
- Drewniak A, Tool AT, Geissler J, van Bruggen R, van den Berg TK, Kuijpers TW. Toll-like receptor-induced reactivity and strongly potentiated IL-8 production in granulocytes mobilized for transfusion purposes. *Blood* 2010;115(22):4588–4596. Doi: 10.1182/blood-2009-11-253245
- Strauss RG. Therapeutic granulocyte transfusions in 1993. *Blood* 1993;81(07):1675–1678
- Klein HG, Strauss RG, Schiffer CA. Granulocyte transfusion therapy. *Semin Hematol* 1996;33(04):359–368
- Price TH, Boeckh M, Harrison RW, et al. Efficacy of transfusion with granulocytes from G-CSF/dexamethasone-treated donors in neutropenic patients with infection. *Blood* 2015;126(18):2153–2161. Doi: 10.1182/blood-2015-05-645986
- Nikolajeva O, Mijovic A, Hess D, et al. Single-donor granulocyte transfusions for improving the outcome of high-risk pediatric patients with known bacterial and fungal infections undergoing stem cell transplantation: a 10-year single-center experience. *Bone Marrow Transplant* 2015;50(06):846–849. Doi: 10.1038/bmt.2015.53
- Garg A, Gupta A, Mishra A, Singh M, Yadav S, Nityanand S. Role of granulocyte transfusions in combating life-threatening infections in patients with severe neutropenia: Experience from a tertiary care centre in North India. *PLoS One* 2018;13(12):e0209832
- Seidel MG, Minkov M, Witt V, et al. Granulocyte transfusions in children and young adults: does the dose matter? *J Pediatr Hematol Oncol* 2009;31(03):166–172. Doi: 10.1097/MPH.0b013e318196a6f9
- Atay D, Ozturk G, Akcay A, Yanasik M, Anak S, Devcioglu O. Effect and safety of granulocyte transfusions in pediatric patients with febrile neutropenia or defective granulocyte functions. *J Pediatr*

- Hematol Oncol 2011;33(06):e220–e225. Doi: 10.1097/MPH.0b013e31821ffdf1
- 25 Zhou B, Song T, Feng Y, et al. Clinical outcome of granulocyte transfusion therapy for the treatment of refractory infection in neutropenic patients with hematological diseases. Ann Hematol 2018;97(11):2061–2070. Doi: 10.1007/s00277-018-3432-4
- 26 Adkins D, Spitzer G, Johnston M, Velasquez W, Dunphy F, Petruska P. Transfusions of granulocyte-colony-stimulating factor-mobilized granulocyte components to allogeneic transplant recipients: analysis of kinetics and factors determining posttransfusion neutrophil and platelet counts. Transfusion 1997;37(07):737–748