Hematopoietic Stem Cell Transplantation (HSCT): Its History, Evolution and Future Perspectives In Evolving World

ABSTRACT

The Hematopoietic Stem Cell Transplantation (HSCT) is known to be a very complex practice which involves the transplantation of multipotent stem cells from a donor to the recipient. For the very recent time period this field has changed into its better form i.e. it has immensely proved itself for the medical care of certain hematological as well as immune-deficiency syndromes. Right now, HSCT is a broadly acknowledged treatment for some dangerous illnesses. It in this manner addresses a genuine helpful expect numerous patients. Due to this widening latitude of transplantation, it has certainly drawn the attention of medical crowd as it now being synchronized in many parts of the world. The present work provides a review of the development strategies of HSCT.

Objectives: Main objectives of this paper are

- Portray the signs for hematopoietic undifferentiated cell transplantation.
- Survey the contradictions to hematopoietic cells transplantation
- Blueprint of confusion of hematopoietic undifferentiated cells transplantation
- Portray the requirement for an all-around coordinated, inter-professional group way to deal with improve care for patients going through hematopoietic undifferentiated cell transplantation

INTRODUCTION

HSCT involves the undifferentiated cells that are being transplanted and are often named as hematopoietic undifferentiated cells. Hematopoietic foundation microorganisms are the youthful cells that lead to myeloid and lymphoid cells from the bone marrow and the outskirts tissues. In basic words, they can be separated into any of the platelets that might be White Blood Cells (WBCs), Red Blood Cells (RBCs) and platelets. They can be multipotent just as pluripotent. Grown up undifferentiated organisms are taken under multipotent cells though undeveloped

immature organisms are viewed as pluripotent. The other name for HSCT is the bone marrow transplantation as these cells are being embedded in the bone marrow. The procedure for HSCT can be carried out through autologous transplant which is obtained from self or either by allogenic transplant which is from a donor other than from self. These cells are obtained from the bone marrow of a person which is referred by the name of peripheral cell. An adult hematopoietic malignancy includes myeloma, leukemia and several other genetic illnesses. It does, in any case, worry about a concern of conceivable dismalness and mortality. Subsequently, there are generous data and correspondence issues engaged with the assent interactions for HSCT. In an official choice, the decisions of various gatherings, like patients, relatives, and medical care experts, meet and cover and this is especially obvious when minor is a patient. Rules are significant for the administration of clinical issues as well as for the HSCT method since it includes significant moral and lawful perspectives. Moral issues concerning transplantation can happen at each period of the system. The clinical decision of whether to play out the methodology, pre-transplantation planning regimens, contributor determination, undifferentiated cell collect technique, the transplantation stage (counting hospitalization during marrow aplasia), and present moment and long haul follow-up care. Additionally, since HSCT is likewise plainly connected with a generous danger of perilous intense inconveniences just as critical organ harmfulness, the personal satisfaction during and after HSCT, contrasted with that related with elective therapies, is a vital issue which ought to be painstakingly talked about and assessed with the patients [41].

Keywords: Hematopoietic stem cell transplantation (HSCT); immune-deficiency syndrome; multipotent stem cells; hematological syndrome.

History of HSCT

HSCT is a very extravagant kind of therapy which is not feasible to everyone. Mainly allogenic transplant that involved the bone marrow transplantation from some other person other than from self was discovered in the 1950 time period. It was performed by Dr. Donnall Thomas who was in that time a great physician as well as a malignancy researcher. It was scientifically investigated in the animal model of mice in which inoculation of healthy bone marrow was done in the bone marrow suppression [1] .The very sequential human bone marrow transplantation was done in New York again by Dr. Donnall Thomas. It was carried out in monozygotic twins

through syngenic transplant that involved obtaining of stem cells from the identical twin [2] .The crucial advancement in the field of HSCT was made by the late 60's. There was an unearthing of HLA i.e. Human Leucocyte Antigen system which was carried out by Dr. Jean Dausset and his other medical fellows. Discovery of HLA allowed the immunologists to understand the working of HLA for their tendency to differentiate between their own proteins versus the outer proteins [3, 4]. The very first achieved allogenic transplantation was performed in Minnesota (U.S. state) during the year of 1968 in a patient who was suffering from immunodeficiency ailment [5].

Today there is a worldwide aggregation of HSCTs that are being reported globally. The rises of transplants are expanding throughout the globe as people are now well informed with the scenario of transplants day by day [6].

Types of HSCTs

Hematopoietic stem cell transplantation is the only established therapy until now. HSCT is mainly done for acute myeloid leukemia, myeloma, etc. HSCT was first done in the year of 1950. During the procedure cells are taken from the chosen donor. On the basis of the donors, HSCT is further divided into two categories:

1. Allogeneic Transplantation/ Donor Transplantation
2. Autologous Transplantation/ Self Transplantation

1. Allogeneic Transplantation

In allogeneic transplantation, the cells are drawn from a donor other than from self. The cells can be acquired either by the donor person otherwise from the bloodstream of a person also known as peripheral section or blood cell. It allows recovery of a person at a higher rate. It is beneficial in the reorganization of deadly cells as extrinsic the reorganization of deadly cells as extrinsic [7].

2. **Autologous Transplantation**

In autologous type of transplantation, cells are taken from self. These cells are cryopreserved and re-infused in the person itself. The chemo/radiotherapy is responsible for the production of anti-tumor effect. It permits the patient's regaining ability from the bone marrow emptiness [8].

Procedure of transplantation

It is an exceptionally perplexing clinical practice which includes transplantation of multipotent immature microorganisms from a contributor to the beneficiary [9, 10]. It very well may be done through autologous transfer which is done from self or either by allogenic relocate which is from a benefactor other than from self [11]. These cells can be gotten from the bone marrow or from the circulatory system of an individual for example fringe undeveloped cells. HSCT for the most part requires four stages, contingent upon the wellspring of the undifferentiated organisms:

(i) Cell assortment- Cells are gathered from the donor. The peripheral blood stem cells are gathered after incitement.
(ii) Handling and thawing- Cells are further handled and thawed. It is done unless required to relocate.
(iii) Undifferentiated cell imbuement-Subsequent to molding, the undifferentiated organisms are implanted intravenously.
The objective is to advance engraftment and allowed the GVT to impact wipe out tumor cells [12, 13].

Worldwide Popularity of HSCT

HSCT was first disclosed in the year of 1950. It was scientifically investigated in the animal model of mice. The very first sequential human bone marrow transplantation was done in the year of 1957 in New York by Dr. Thomas in monozygotic twins. According to the MS Society experts, bone marrow transplant is most useful in younger patients [14]. Till the year of 2017, there was only one hospital in Chennai that allowed storing of cord stem cells of the babies, but with the prevailing practices around the world there is an immense increase in the storage of these cells now.

Other than that there is a non-profit organization named Worldwide Network for Blood and Marrow Transplantation (WNBMT) that works for the HSCT. There were 50,417 first HSCT, 21,516 allogeneic which are 43% 28,901 autologous which is 57% revealed from 1,327 focuses in 71 nations which were for Leukemia and few were for the allogenic. Utilization of allogeneic and the other transplantation, utilization for blood givers for transplant and extents for the illness sign fluctuated fundamentally among nations and mainland districts.

Analysis and data collection for HSCT worldwide

The relationship of the full scale financial elements with relocate rates was assessed by single direct and numerous straight relapse examinations, utilizing the customary least square technique. The direct connection, joining the large scale monetary elements and relocate after change was estimated by measurements; degree of 6% was said to be critical. The numerous direct relapse investigations the reliant factors were changed to bring up the straight affiliations. Some places of the world were avoided the numerous financial examinations due to missing data on Governmental Health Care uses. Some area rates were remembered not as of yet various relapse examinations since information from an excessive number of nations were absent. Starting around 1990 all EBMT individuals and associated nonmembers have been requested every year to give an account of an overview sheet the numbers from new patients by sign, undifferentiated cell source and giver type[15] .Furthermore, the structure gathers nonexclusive data on the quantities of extra re-or numerous transfers, on the level of line blood HSCT and, starting around 1999, on the level of transfers with decreased power molding (RIC) HSCT. Information are approved by the announcing group, which gets a PC printout of the entered information, and by cross checking with public vaults. Groups are exposed to on location visits. The EBMT review was embraced by the General Assembly as a compulsory self-announcing framework. It presently shapes a basic piece of a complete quality confirmation program JACIE (Joint Accreditation Committee of the International Society for Cellular Therapy ISCT and the European Group for Blood and Marrow Transplantation EBMT)[16, 17]

Rate of Transplantation

Relocate rates were characterized as the quantity of HSCT per 10 million occupants. They were registered by illness sign and benefactor type for every nation, as recently characterized. Relocate rates were evaluated for all HSCT and independently for autologous, allogeneic and irrelevant HSCT. They were additionally evaluated for RIC allogeneic HSCT, DLI and rope blood HSCT [18] .Transplant rates allude to the quantity of transfers in a given nation contrasted with its own populace. The study can't adapt for patients who cross public boundaries and accept their HSCT in an unfamiliar country. Notwithstanding outright transfer rates, the extent of patients relocated with bone marrow or fringe blood was determined by illness and principle sickness class. Populace information was acquired from the US registration office. [19].

Development of HSCs

In vertebrates, the creation of blood immature microorganisms is refined by the portion and detail of particular undeveloped cells in an assortment of locales that change during improvement. In well evolved creatures; the successive destinations of hematopoiesis incorporate the yolk sac, a region encompassing the dorsal aorta named the Aorta-Gonad Mesonephros (AGM) area, the fetal liver, lastly the bone marrow [20] .Similarly, an intraembryonic wellspring of grown-up HSCs in mice able to do long haul reconstitution of illuminated hosts dwells in the AGM region [21] .Additional hematopoietic action in the mouse incipient organism was distinguished thusly in different destinations, remembering the umbilical corridors and the allantois for which hematopoietic and endothelial cells are colocalized. Umbilical veins need hematopoietic potential, recommending that an order exists during conclusive hematopoiesis in which HSCs emerge prevalently during conduit determination [22]. Likewise, critical quantities of HSCs are found in the mouse placenta almost incidental with the presence of HSCs in the AGM locale and for a very long time from that point. Placental HSCs could emerge through all over again age or colonization upon dissemination, or both [23].

Formative time windows for hematopoietic locales in zebra fish.

Basically dependent on morphology it has been recommended that as the AGM structures, "hemogenic endothelial" cells in the ventral mass of the aorta, rather than hemangioblasts, bud off HSCs. The program of hemogenic endothelial cell improvement might be managed uniquely in contrast to that of hypothetical hemangioblasts, considering that the record factor necessities vary. For instance, the record factor Runx1 is important for blood development from hemogenic endothelium however not from yolk sac hemangioblasts [24].

The possibility to create hematopoietic, endothelial, and smooth muscle cells has been credited to another cell type, named the mesoangioblast, present in the aorta[25] .Other work has shown that mesenchymal cell populaces in the sub aortic area jab through the aorta and bud off HSCs [26].

Formative Relationships between the Yolk Sac and the AGM

Similarly as with mesodermal subordinates, all platelets in early stage, fetal, and grown-up creatures may emerge from a little arrangement of cells during improvement. Proof for and against this idea is available in the writing. Destiny planning in the pre-gastrula Xenopus incipient organism with fluorescent color infused into individual blastomeres of the 32-cell undeveloped organism showed that various blastomeres add to crude hematopoiesis and authoritative HSC creation [27] ·Technical parts of destiny planning of the 32-cell incipient organism have been tested [28] .Since utilitarian movement of immature microorganisms as dictated by transplantation into illuminated grown-ups happens a lot later (at day 11), it is conceivable that cells of the yolk sac colonize the AGM through the flow. Indeed, HSC-like movement of yolk sac cells (as characterized by a neonatal transplantation measure) [29] is distinguished as right on time as day 9, despite the fact that course has begun at that point.

Does the Yolk Sac Contain HSCs?

In light of cell destiny planning and transplantation tests in avian and land and water proficient species, the AGM has been generally seen as the chief site for HSC creation during vertebrate turn of events. In later work, Nishikawa and associates have additionally tested the creed that the yolk sac needs authoritative hematopoietic stem cells. The destiny of early stage tissues was followed in transgenic mice in which Runx1 administrative components drive articulation of hormonally actuated Cre recombinase [30].

Transcription Factors in Hematopoietic Development

As inherent determinants of cell aggregate, record factors give a section highlight unwinding how HSCs create during embryogenesis and how heredity limited separation is modified [31].Late surveys give extra conversation of record factors in various hematopoietic ancestries [32, 33, 34, 35] Bits of knowledge into the elements of the basic record factors have laid transcendently on discoveries from either traditional or contingent quality knockouts in mice and from constrained articulation explores, all supplemented by formative investigations in other model creatures (e.g., zebra fish, chicken, Drosophila, Xenopus). The record factors that are basic for hematopoiesis include essentially all classes of DNA-restricting proteins, rather than leaning toward a particular family. A momentous element of record factors in the hematopoietic framework is that the larger

parts are engaged with chromosomal movements or with physical changes in human hematopoietic malignancies.

Signs for HSCT

HSCT is just shown in Childhood Cerebral Adrenal Leukodystrophy (CCALD) and is the single treatment methodology accessible in this aggregate to exhibit enhancement of sickness [36] .The viability of HSCT in X-ALD is probably not going to be in cross-remedy. HSCT might capture the neuro inflammatory demyelinating process by supplanting useless microglia with bone-marrow inferred macrophages yet this component has not been completely clarified [37].

Complications

Chemotherapy and radiation of preparative routine alongside post-relocate immunosuppression can actuate extreme pancytopenia in the principal week following mixture of hematopoietic undifferentiated cells which can prompt hazardous diseases. This relies upon the kind and the portion of chemotherapy regulated and factors identified with the beneficiaries [38] .Chemotherapy causes an annihilation of sound, ordinary bone marrow items including neutrophils, macrophages, monocytes, and lymphocytes. Contaminations are the main sources of dreariness during relocate time [39] .In the pre-time for the graft frame contaminations are followed by contagious diseases prevail because of lesser count of the WBCs tallies. The main microbes in the after graft time are the different microorganisms like Pneumocystis and the recently referenced Aspergillus. Likewise, mucositis poisonousness because of chemotherapy disturbs the obstructions ensuring against irresistible specialists, and utilization of inhabiting intravenous catheters gives another mean of passageway of irresistible researchers. Immunization is prescribed for the accompanying specialists as indicated by the rules: Pneumococcal Form (PCV), Tetanus-Diphtheria-Pertussis (TDaP), Haemophilus influenza, meningococcal form, onactivated polio, inactivated flu and Measles, mumps and rubella (MMR). Several regimens of prophylaxis have been proposed to forestall disease relying upon the danger separation of patients (generally safe, high-hazard, treatment of progressing graft-versus-host disease GVHD).GVHD can be intense or persistent. Despite the fact that GVHD has generally been named intense or constant dependent, currently it is broadly perceived as broad cover. Pediatric HSCT survivors are bound to encounter mental trouble and often a problematic life in

the future [40].In spite of the fact that results of HSCT will in general be acceptable and cases show impressive upliftment after a general time period. On an all strategy relies with the related consequences such as huge horribleness, mortality, and long haul medical problems.

Coronavirus pandemic and its effect on HSCT

As of now, the world is seeing a wellbeing emergency as COVID-19 pandemic [42]. For oncologists, particularly for immature microorganism relocate subject matter experts, the pressure is high to perform to their best of capability. Despite rehearsing every one of the right advances and following suggestions, last-minute obstacles can upset every one of the procedures for which a transfer group ought to be prepared to handle the unpredicted circumstances. Not many of them could be[42] giver getting tainted between leeway for gift and the genuine date of the cell apheresis, or[43] reap focus staff falling wiped out to COVID-19 sickness upon the arrival of collect, or[44] hardships to move gathered undifferentiated organisms across the boundary because of movement limitations. Steps, for example, dropping the elective medical procedures and strategies, mentioning each unit of red platelets in turn, reverifying on the signs of blood item request demands, and calling for more blood gift drives could help the blood communities and medical clinics to hold over the COVID-19 crisis[45].To spare the scant assets (customary and ICU beds, work force, blood items, and so forth) that are relied upon to be popular during the COVID-19 flood, relocate focuses have been deferring undifferentiated organism transfers at whatever point clinically conceivable[46].

Benefits and detriments of HSCT

Collection Method	Benefits	Detriments
Bone Marrow	Single assortment	Acted in an intense consideration setting as it requires general sedation
	No requirement for uncommon catheter position	More slow neutrophil and platelet engraftment
	No requirement for development factors	Related with higher paces of bleakness

CONCLUSION

Nowadays transplantations are becoming real hope for many patients. HSCT relocate use in clinical practice has been growing somewhat recently, and numerous clinical preliminaries are as yet progressing to survey its adequacy in various ailments. The number of patients has risen since past two decades worldwide. The field of tissue and cell donation and banking is highly regulated in many parts of the world. Hematopoietic transplantation is a therapeutic procedure for some immunological and inherited diseases. As COVID-19 is a developing illness, for independent direction, focusing on reports from neighborhood wellbeing specialists, assessing the most recent information, and keeping break rules is fundamental to guarantee consistency in the way to deal with relocate patients. The main objective lies in portraying and surveying the transplantation schemes throughout the world. The main motive lies in acknowledging the people all around the globe about the great advancement of transplant with a far better rate of recuperation.

ACKNOWLEDGEMENT

I make a move to offer my significant thanks and profound respect to my instructor Dr. Pankaj Mehta for her model direction, checking and steady consolation throughout this undertaking. The gift, help and direction given by her an opportunity to time will convey me far in the excursion of life on which I am going to set out.

I might likewise want to thank my folks and companions who helped me a great deal in settling this task inside the restricted period.

REFERENCES

1. BARNES DW, CORP MJ, LOUTIT JF, NEAL FE. Treatment of murine leukaemia with X rays and homologous bone marrow; preliminary communication. Br Med J. 1956 Sep 15;2(4993):626-7. [PMC free article] [PubMed]
2. THOMAS ED, LOCHTE HL, LU WC, FERREBEE JW. Intravenous infusion of bone marrow in patients receiving radiation and chemotherapy. N Engl J Med. 1957 Sep 12;257(11):491-6. [PubMed]

3. Dausset J. Iso-leuko-antibodies. Acta Haematol. 1958 Jul-Oct; 20(1-4): 156-66. https://www.ncbi.nlm.nih. gov/pubmed/13582558
4. Van Rood JJ. The detection of transplantation antigens in leukocytes. Semin Hematol 1968 Apr; 5(2): 187-214. https://www.ncbi.nlm.nih.gov/ pubmed/4871670
5. Gatti RA, Meuwissen HJ, Allen HD, Hong R, Good RA. Immunological reconstitution of sex-linked lymphopenic immunological deficiency. Lancet. 1968 Dec 28;2(7583):1366-9. [PubMed]
6. Pasquini MC, Wang Z, Horowitz MM, Gale RP. 2010 report from the Center for International Blood and Marrow Transplant Research (CIBMTR): current uses and outcomes of hematopoietic cell transplants for blood and bone marrow disorders. Clin Transpl. 2010:87-105. [PubMed]
7. Types of stem cell and bone marrow transplants. (n.d.). https://www.cancer.org/treatment/treatments-and-side-effects/treatment-types/stem-cell-transplant/types-of-transplants.html
8. Bone marrow transplant: MedlinePlus medical encyclopedia. (n.d.). MedlinePlus - Health Information from the National Library of Medicine. https://medlineplus.gov/ency/article/003009.htm
9. E. J. Chow, L. Anderson, K. S. Baker et al., "Late effects surveillance recommendations among survivors of childhood hematopoietic cell transplantation: a Children's oncology group report," Biology of Blood and Marrow Transplantation, vol. 22, pp. 782–795, 2016. View at: Publisher Site | Google Scholar
10. S. Joshi, B. N. Savani, E. J. Chow et al., "Clinical guide to fertility preservation in hematopoietic cell transplant recipients," Bone Marrow Transplantation, vol. 49, pp. 477–484, 2014.View at: Publisher Site | Google Scholar
11. A. K. Singh and J. P. McGuirk, "Allogeneic stem cell transplantation: a historical and scientific overview," Cancer Research, vol. 76, no. 22, pp. 6445–6451, 2016, [Epub ahead of print].View at: Publisher Site | Google Scholar
12. Cryopreservation of hematopoietic stem cells. (n.d.). PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2075525/

13. Rowley SD, Bensinger WI, Gooley TA, Buckner CD. Effect of cell concentration on bone marrow and peripheral blood stem cell cryopreservation. Blood. 1994;83:2731–2736. [PubMed] [Google Scholar]
14. Frederick, M. C., & Bourdette, D. (2017). MS and bone marrow transplantAbout multiple sclerosis and hematopoietic stem cells in the treatment of multiple sclerosis. Neurology, 88(22), e219-e220.
15. Retrieved November 1, 2020, from https://multiplesclerosisnewstoday.com/news-posts/2020/11/13/bone-marrow-transplant-most-useful-for-younger-multiple-sclerosis-patients-with-high-disease-activity-ms-society-experts-suggest/?cn-reloaded=1
16. Gratwohl A . Bone marrow transplantation activity in Europe 1990. Report from the European Group for Bone Marrow Transplantation (EBMT). Bone Marrow Transplant 1991; 8: 197–201.
17. Urbano-Ispizua A, Schmitz N, de Witte T et al. Allogeneic and autologous transplantation for haematological diseases, solid tumours and immune disorders: definitions and current practice in Europe. Bone Marrow Transplant 2002; 29: 639–646.
18. Kvalheim G, Urbano-Ispizua A, Gratwohl A . Regulatory aspects and accreditation of the clinical use of hematopoietic progenitor cells in Europe. J Biol Regul Homeost Agents 2001; 15: 79–80
19. Gratwohl A, Passweg J, Baldomero H et al. for the Accreditation Committee of the European Group for Blood and Marrow Transplantation (EBMT). Economics, health care systems and utilisation of haematopoietic stem cell transplants in Europe. Br J Haematol 2002; 117: 451–468.
20. US Census Bureau. (2005, August 8). Change in stem cell source for hematopoietic stem cell transplantation (HSCT) in Europe: a report of the EBMT activity survey 2003. Census.gov. https://www.census.gov
21. J.L. Galloway, L.I. Zon Ontogeny of hematopoiesis: examining the emergence of hematopoietic cells in the vertebrate embryo Curr. Top. Dev. Biol., 53 (2003), pp. 139-158
22. A.M. Muller, A. Medvinsky, J. Strouboulis, F. Grosveld, E. Dzierzak Development of hematopoietic stem cell activity in the mouse embryo Immunity, 1 (1994), pp. 291-301
23. C. Gekas, F. Dieterlen-Lievre, S.H. Orkin, H.K. Mikkola The placenta is a niche for hematopoietic stem cells Dev. Cell, 8 (2005), pp. 365-375
24. K. Ottersbach, E. Dzierzak The murine placenta contains hematopoietic stem cells within the vascular labyrinth region Dev. Cell, 8 (2005), pp. 377-387

25. T.E. North, M.F. de Bruijn, T. Stacy, L. Talebian, E. Lind, C. Robin, M. Binder, E. Dzierzak, N.A. Speck Runx1 expression marks long-term repopulating hematopoietic stem cells in the midgestation mouse embryo Immunity, 16 (2002), pp. 661-672
26. G. Cossu, P. Bianco Mesoangioblasts–vascular progenitors for extravascular mesodermal tissues Curr. Opin. Genet. Dev., 13 (2003), pp. 537-542
27. J.Y. Bertrand, S. Giroux, R. Golub, M. Klaine, A. Jalil, L. Boucontet, I. Godin, A. Cumano Characterization of purified intraembryonic hematopoietic stem cells as a tool to define their site of origin Proc. Natl. Acad. Sci. USA, 102 (2005), pp. 134-139
28. A. Ciau-Uitz, M. Walmsley, R. Patient Distinct origins of adult and embryonic blood in Xenopus Cell, 102 (2000), pp. 787-796
29. M.C. Lane, M.D. Sheets Primitive and definitive blood share a common origin in Xenopus: a comparison of lineage techniques used to construct fate maps Dev. Biol., 248 (2002), pp. 52-67
30. J. Palis, R.J. Chan, A. Koniski, R. Patel, M. Starr, M.C. Yoder Spatial and temporal emergence of high proliferative potential hematopoietic precursors during murine embryogenesis Proc. Natl. Acad. Sci. USA, 98 (2001), pp. 4528-4533
31. Close I.M. Samokhvalov, N.I. Samokhvalova, S. Nishikawa Cell tracing shows the contribution of the yolk sac to adult haematopoiesis Nature, 446 (2007), pp. 1056-1061
32. S.H. Orkin Diversification of haematopoietic stem cells to specific lineages Nat. Rev. Genet., 1 (2000), pp. 57-64
33. S.L. Nutt, B.L. Kee The transcriptional regulation of B cell lineage commitment Immunity, 26 (2007), pp. 715-725
34. H. Iwasaki, K. Akashi Myeloid lineage commitment from the hematopoietic stem cell Immunity, 26 (2007), pp. 726-740
35. Close S.I. Kim, E.H. Bresnick Transcriptional control of erythropoiesis: emerging mechanisms and principles Oncogene, 26 (2007), pp. 6777-6794
36. Close E.V. Rothenberg Negotiation of the T lineage fate decision by transcription-factor interplay and micro environmental signals Immunity, 26 (2007), pp. 690-702
37. Mahmood A, Raymond GV, Dubey P, Peters C, Moser HW. Survival analysis of haematopoietic cell transplantation for childhood cerebral X-linked adreno leuko dystrophy: a comparison study. Lancet Neurol. (2007) 6:687–92. doi: 10.1016/S1474-4422(07)70177-1

38. Hematopoietic stem cell transplantation - StatPearls - NCBI bookshelf. (2021, July 1). National Center for Biotechnology Information. https://www.ncbi.nlm.nih.gov/books/NBK536951/
39. Horowitz MM, Gale RP, Sondel PM, Goldman JM, Kersey J, Kolb HJ, Rimm AA, Ringdén O, Rozman C, Speck B. Graft-versus-leukemia reactions after bone marrow transplantation. Blood. 1990 Feb 01;75(3):555-62. [PubMed]
40. The rise of hematopoietic stem cell transplantation. (2020, June 16). Reinsurance Group of America
41. Pluripotent and multipotent stem cells. (n.d.). MilliporeSigma | United States.
42. Sahu KK, Mishra AK, Lal A. Novel coronavirus (2019-nCoV): update on 3rd coronavirus outbreak of 21st century. QJM. 2020.Mar 3. pii: hcaa081.
43. Ueda M, Martins R, Hendrie PC, McDonnell T, Crews JR, Wong TL, et al. Managing cancer care during the COVID-19 pandemic: agility and collaboration toward a common goal. J Natl Compr Cancer Netw. 2020;20:1–4.
44. Sahu KK, Lal A, Mishra AK. Latest updates on COVID-2019: a changing paradigm shift. J Med Virol. 2020. Mar 20.
45. Pagano MB, Hess JR, Tsang HC, Staley E, Gernsheimer T, Sen N, et al. Prepare to adapt: blood supply and transfusion support during the first 2 weeks of the 2019 Novel Coronavirus (COVID-19) pandemic affecting Washington State. Transfusion. 2020 Mar 21.
46. Sahu KK, Jindal V, Siddiqui AD. Managing COVID-19 in Patients With Cancer: A Double Blow for Oncologists. JCO Oncol Pract. 2020 Apr 17:OP2000167.