International Journal of Hospital Research 2021, 10 (4)
http://ijhr.iums.ac.ir
Research Article

IJHR

Open Access

Prediction of demand for blood bank products according to blood groups by using artificial neural networks

Ali Asghar Moslemi[1,] Mahdi Yousefi Nejad Attari[1*]

[1] Department of Industrial Engineering, Bonab Branch, Islamic Azad University, Bonab, Iran

Abstract

Background and Objectives: A limited supply chain opportunity between blood donation and blood transfusion requires the optimization of each stage in the supply chain of the blood, to achieve more effective blood supply management in blood centers and hospitals. Since in previous researches the demand for blood products has not been predicted for the separation of blood groups, so in this study, due to the diversity of different blood groups, the demand for blood products has been predicted using artificial neural networks. (Case study: Zanjan blood Transfusion Network).

Methods: We gathered information on all actual blood donations from 21 March 2014 to 21 September 2016 from the national donor database.

Goals of this study are to evaluate trends of FFP, PLT and RBC based on blood groups' demand and supply, and also to predict how FFP, PLT and RBC will be developed over 30 months, using neural network model

Results: The best neural network architecture for predicting the demand for blood products had two delays and five neurons in the hidden layer. Also, the results show that the error value is close to each other in all three blood products but has different values. Accuracy in predicting blood products demand is done by calculation error indexs for example MAD and MSE.

Conclusions: The results showed that this method is capable of predicting. Accordingly, in order to obtain more suitable models, future researchers are suggested to study the combination of artificial neural networks with meta-algorithms. The accuracy of prediction in platelet blood product in the mean square error index for her O^- with the value of 7.401 has the lowest value.

Keywords: Blood products, Artificial Neural Networks (ANN), Supply Chain (SC).

Background and Objectives

Blood supply chain

The reliability of the supply chain generally is of special importance. The reliability of the supply chain is related to the products` flow from the supply points to the demand centers such as hospitals be not less than the total demand[1]. During recent years, global health care have made focus on the improvement of supply chains[2,3] . The restricted time of the supply chain between the blood donation and blood transfusion requires the optimization of every stage of the blood supply chain[4] that leads to more efficient blood inventory management in the blood centres and hospitals[5].

Main reasons for attending the healthcare supply chain include reducing costs, consuming resources with the intended level of services, preserving patient's safety and public health[6].

*Corresponding Author: Mahdi Yousefi Nejad attari
Email: myousefi@bonabiau.ac.ir

According to Privett and Gonzalez[3], the main challenges in the health supply chain include the lack of assurance in the demand, inventory and order management, and expiration and restriction of human recourses. For instance, the lack of accurate information such as the demand information can force the administration to decide an order that can lead to the wasting of recourses and generating health care costs. These challenges are of particular importance when the intended product has a short lifetime.

According to Peryot and Gonzalez[3], have been include the lack of assurance in the demand, inventory and order management, and expiration and restriction of human recourses.

The excessive demand for blood, in addition to the imposition of inordinate costs on the blood transfusion center, causes the reduction of blood bank supply, reduction of blood unit quality and increase of wastes resulting from that[7]. The World Health Organization (WHO) has estimated the amount of blood needed for every patient bed 5 to 15 units per year. It was evident that the cooperation of specialists of surgery, anaesthesia, and oncology in estimating the real bloodshed probability and not saving the unnecessary extra blood has resulted in reducing the additional costs[8].

Although the suppliers experienced the short-time reduction of the blood demand due to correct blood management, models indicated that the blood demand is considerably increased due to the senility of societies[9].

Death risk of individuals around the world can be reduced by blood and its products. It has been estimated that in the US, 6.5 million patients would have died if they don't receive the blood for annual infusion[10].

Predication of blood products

As mentioned, the importance of blood products in the health of medicinal care has prompted many efforts in the case of blood demand and inventory. Lack of blood inventory and the frequency of diseases such as thalassemia in Iran, has triggered researches on blood demand to first, help healthcare authorities and policymakers in proper planning of blood demand and supply and second, Maintain patient safety and quality of health care. In this respect, the researcher has predicted the demand for blood bank products separately sorted by blood groups with a data mining approach using the artificial neural networks. The artificial neural networks can appropriately predict the past procedures toward the future by proper regulation of some of the parameters. This study tries to predict the demand for blood products by blood groups, using the neural network model. Central questions of this study are: How much is the potency of blood groups in predicting blood demand and, what is the best neural network architecture for this prediction[11].

Artificial neural networks (ANNs)

Artificial neural networks are learning algorithms inspired by human brains. The chief architecture of ANN model consists of three parts, including the input layer, the hidden layer(s) and the output layer. Each layer consists of some neurons, which have linear or non-linear activation functions. Except for the input layer, each layer is connected to the previous layer, through weighted links. Learning process in neural networks consists of two steps: feedforward and backpropagation. In feedforward step, errors are calculated, and in the backpropagation, weights are adjusted. This procedure is recurrent until the algorithm converges. We studied the multi-layered perceptron (MLP) neural network. The dataset was randomly partitioned into training and validation sets with the 70/30 ratio[11].

In this research, the artificial neural network was used for analysing the data. The artificial neural network has been formed by artificial neurons. The neuron or node is the smallest unit of information processing that forms the foundation of the function of artificial neural networks. Each of the neurons receives the inputs and produces an output signal after processing them. So, every neuron in the network acts as the center of information process and distribution and has its specific input and output[12]. The artificial neural network is one of the calculating methods that, by the help of the learning process and processors such as a neuron, makes effort to present a monograph between the input space (input layer) and optimal space (output layer) by recognizing the internal relations between the data. The latent layer (s) process the information received from the input layer and submit them to the output layer. Every network is educated by the reception of some examples. Education is a process that leads to learning in the end. The learning of the network is done when the communicative weights between the layers are changed in a way that the difference between the predicted amounts and calculated ones is acceptable. In such a condition, the learning process has been provided. These weights express the memory and knowledge of the network. The educated artificial neural networks can be used for anticipating the outputs appropriate for the new data set[13]. With regard to the structure of the artificial neural network, its general features, high processing speed, the ability for learning pattern by pattern determination method, ability to the generalization of knowledge after the learning, flexibility in undesirable errors and lack of considerable disarrangement in the situation of the emergence of a problem in some parts of connections are due to the distribution of network weights[14]. The ANN is a set of nodes and links between them. It is also composed of a set of simple elements that shapes a complex unit in relation to each other. ANN are planned to obtain various pieces of information. The nodes are capable of receiving input, processing them, and producing output. The variables in the ANN contain the quantity of hospitals' blood demand and the rate of blood return units (as fines) that, after solving the model, predict the optimal rate of blood units delivered to hospitals[15].

Managers of blood transfusion centers to supply the blood products needed by hospitals should predict the amount of blood used and identify the factors affecting the demand for blood products. The purpose of this paper is to use ANN model to evaluate the demand trend of FFP, PLT and RBC with eight blood groups of supply and demand A-, A +, AB-, AB +, B-, B +, O- and O + and to predict the consumption of this Products are within 30 months.

Methods

In this study, evaluation criteria include R-squared (R2), mean square error (MSE) and root mean squared error (RMSE) , have been used for selecting the best model of artificial neural networks network with with different neurons . R-squared (R2) is a statistical measure that represents the proportion of variance in the dependent variable that is predictable from the independent variable(s) in a regression model. R-squared (R2) formulation is shown in the equation (1). The mean square error (MSE) is the average of the squared difference between the estimated values and actual values. We can see MSE formulation in the equation (2). Another error metric you may meet is the root mean squared error (RMSE). As the name suggests, it is the square root of the

MSE. Because the MSE is squared, its units do not match that of the original output. Researchers will often use RMSE to change the error metric back into similar units, making interpretation easier. Since the MSE and RMSE both square the residual, they are similarly affected by outliers. The RMSE is analogous to the standard deviation (MSE to variance) and is a measure of how large your residuals are spread MAE and MSE indices can have values from 0 to extremely positive, so the higher the value of these two criteria, the more difficult it is to describe the performance of the forecasting model. In other words, the confidence in the accuracy of the predicted values decreases.

. RMSE formulation is shown in the equation (3).

$$R^2 = 1 - \frac{\sum_{k-1}^{n}\left(u_{a,k} - u_{p,k}\right)^2}{\sum_{k-1}^{n}\left(u_{a,k}\right)^2} \quad (1)$$

$$MSE = \frac{\sum_{k=1}^{n}\left(u_{a,k} - u_{p,k}\right)^2}{n} \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{k=1}^{n}\left(u_{a,k} - u_{p,k}\right)^2}{n}} \quad (3)$$

Available donation data

A data set including information on all actual whole blood donations from 21 March 2014 to 21 September 2016 is obtained by Zanjan Blood Bank from the national donor database. The data of this research have been gathered based on the data available in the blood bank of Zanjan province. For this subject, Database banks and computer networks of Zanjan blood Transfusion Network were used.

from 21 March 2014 to 21 September 2016, on average 5% of the whole blood donations did not result in the distribution of FFP, PLT and RBC units to a hospital. We therefore supposed that the number of FFPs, PLTs and RBCs distributed to hospitals is 0.95 times the total number of whole blood donations.

Blood Donation and transfusion data were analyzed using computer MATLAB software.

Results

In this section, the frequency of three blood products has been modelled based on different blood groups, using the neural network model. For this purpose, the number of neurons and delays has been calculated by trial and error. Model performance was measured by MSE, RMSE, and MAP indexes.

In the predictions made, initially, by default, three neurons were considered as the number of nerve cells and the number of errors was also observed. Then, with trial and error, the number of neural cells for the next steps was tested based on the best amount and two neurons less and more to select the best artificial neural networks in terms of function.

Prediction of blood groups of FFP product

In the prediction of blood groups of FFP product, in the beginning, three neurons with the number of delay 1 have been used in the latent layer. By calculating the error indexes, the number of neurons in the delay 1 has been increased and the best amount has resulted in five neurons. In the next step, the number of delays has been increased to 6 with regard to being 6-month of the number of data and the best function of the artificial neural networks has been concluded in two delays. The results for the other blood groups also have been continued with two delays and respectively with three, four, five, six and seven neurons. The results have been represented in Table 1.

With regard to this matter that the best function of artificial neural networks in demand for blood products has occurred in five neurons, the results related to the correlation coefficient has been represented separately for test data, validation, and artificial neural networks education. For instance, the results for the blood group A^- has been presented in the Fig.1.

Table 1. Prediction of blood groups of FFP product with different neurons

	Number of neurons								
	3			5			7		
Blood	MSE	RMSE	MAP	MSE	RMSE	MAP	MSE	RMSE	MAP
A-	38.797	6.228	5.542	2.047	1.430	0.292	38.769	6.226	5.538
A+	509.489	22.571	72.784	177.284	13.314	25.326	711.273	26.669	101.610
AB-	19.787	4.4482	2.827	5.639	2.374	0.806	18.974	4.355	2.710
AB+	106.494	10.319	15.213	80.274	8.959	11.468	130.082	11.405	18.583
B-	44.967	6.705	6.424	17.694	4.206	2.528	37.974	6.162	5.424
B+	42.119	6.489	6.017	31.822	5.641	4.546	362.298	19.034	51.756
O^-	45.150	6.719	6.450	9.050	3.008	1.293	33.120	5.7549	4.731
O+	307.198	17.527	43.885	81.340	9.018	11.620	256.41	16.012	36.63

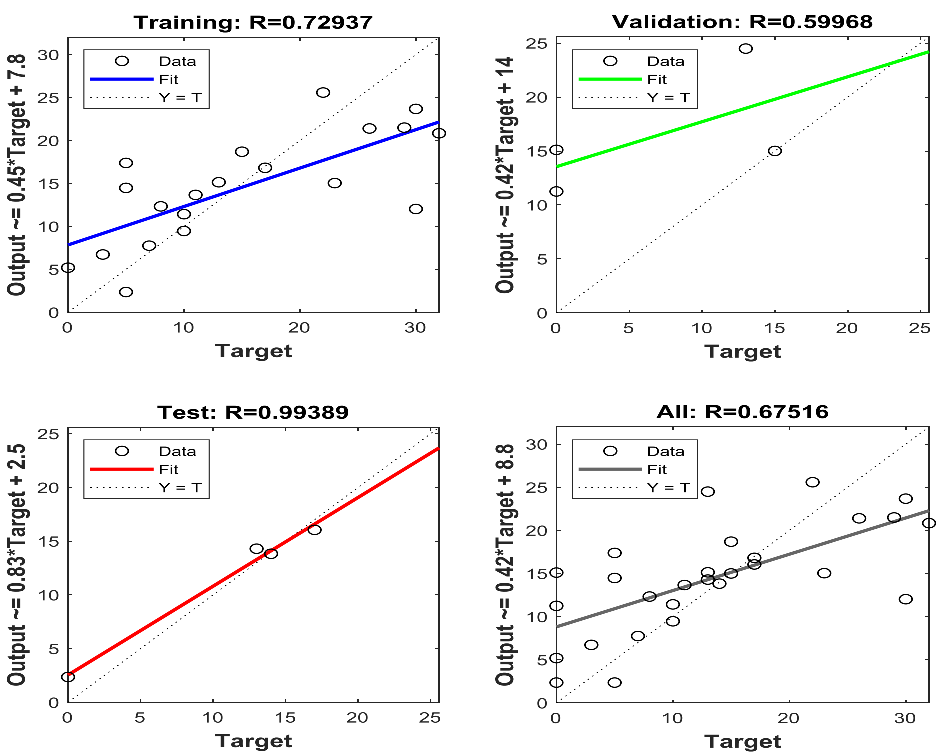

Fig.1. Correlation coefficients for education data, validation and testing the blood group A^-

The prediction of blood groups of PLT product has been presented in Table 2.

Table 2. Prediction of blood groups of PLT product with different neurons

	2			5			7		
Blood	MSE	RMSE	MAP	MSE	RMSE	MAP	MSE	RMSE	MAP
A^-	29.932	5.471	5.084	8.123	2.850	1.380	51.954	7.208	8.825
A+	287.546	16.957	48.844	123.012	11.091	20.896	476.454	21.828	80.933
AB-	22.634	4.758	3.845	10.324	3.213	1.754	38.232	6.183	6.494
AB+	116.044	10.772	19.712	64.239	8.015	10.912	211.087	14.529	35.856
B^-	52.778	7.265	8.965	13.034	3.610	2.214	56.321	7.505	9.567
B+	49.234	7.017	8.363	26.674	5.165	4.531	289.435	17.013	49.165
O^-	25.441	5.044	4.322	7.401	2.720	1.257	67.232	8.200	11.420
O+	219.342	14.810	37.259	66.045	8.127	11.219	432.059	20.786	73.392

The prediction of blood groups of PLT product has been presented in Table 3.

Table 3. Prediction of blood groups of RBC product with different neurons

	3			5			7		
Blood	MSE	RMSE	MAP	MSE	RMSE	MAP	MSE	RMSE	MAP
A^-	29.981	5.475	4.440	4.823	2.196	0.714	44.354	6.660	6.569
A+	435.341	20.865	64.476	113.365	10.647	16.790	435.354	20.865	64.478
AB^-	23.345	4.832	3.457	9.046	3.008	1.340	29.734	5.453	4.404
AB+	99.034	9.952	14.667	65.476	8.092	9.697	154.345	12.424	22.859
B^-	57.651	7.593	8.538	13.077	3.610	1.930	45.456	6.742	6.732
B+	49.712	7.051	7.363	26.768	5.174	3.964	276.234	16.620	40.911
O^-	47.612	6.900	7.052	11.922	3.453	1.766	54.234	7.364	8.032
O+	288.432	16.983	42.718	77.245	8.789	11.440	109.741	10.476	16.253

The results of Tables 1, 2 and 3 revealed that the best artificial neural networks model for predicting the demand for blood bank products separately sorted by the blood groups in Zanjan blood transfusion network has had two delays and five neurons in the latent layer. In such a way that the results related to the study pf amount of mean squared error for blood groups of FFP product in the Table 1 revealed that the mean squared error for the blood groups A-, A+, AB-, AB+, B^-, B+, O^- and O^+ has been, respectively, calculated 2.047, 177.284, 5.639, 80.274, 17.694, 31.822, 9.050 and 81.340. Furthermore, the amount of root means square error in FFP blood products for the blood groups has been obtained, respectively, 1.430, 13.314, 2.374, 8.989, 4.206, 5.641, 3.008 and 9.018. The results related to the blood groups of PLT product in Table 2 revealed that the mean squared error for the blood groups A-, A+, AB-, AB+, B^-, B+, O^- and O^+ has been respectively, calculated 8.123, 123.012, 10.324, 64.239, 13.034, 26. 674, 7.401 and 66.045. In addition, the amount of root means square error in the blood products of PLT for the blood groups has been, respectively, calculated 2.850, 11.091, 3.213, 8.015, 3.610, 5.165, 2.720 and 8.127. The results related to the blood groups of RBC product in Table 3 revealed that the mean squared error for the blood groups A-, A+, AB-, AB+, B^-, B+, O^- and O^+ has been, respectively, calculated 4.823, 13.365, 9.046, 65.476, 13.077, 26.768, 11.922 and 77.245. Furthermore, the amount of root means square error in the blood product

RBC for the blood groups has been, respectively, calculated 2.196, 10.647, 3.008, 8.092, 3.610, 5.174, 3.543 and 8.789.

Conclusion

The rapid processes between blood donation and blood transfusion in the blood supply chain need the optimization of every stage especially to access more efficiency in blood inventory management in the blood centers and hospitals. Of the main reasons for paying attention to the supply chain of medicinal care, it can be referred to as the reduction of medicinal care and consumption in the recourses by maintaining the level of services needed for the consumer, patients' safety and their public health. The importance of blood as a product in the health of medicinal care has caused many efforts to be done in the case of blood demand and inventory. Furthermore, with regard to this matter that the blood inventory in Iran is less in comparison to the global average and also with regard to this that the diseases such as thalassemia in our country are more than the other regional countries, so the exact prediction of the demand for blood, the first step, can aware the authorities and policymakers of health domain for proper planning to be able to supply the demand for blood in the country and helps them to consider appropriate planning in this regard and, in the second step, provides the responsibility to the patients and maintains the quality of health cares.

In general, it can be said that the prediction of blood products by blood groups in the following cases will help managers:

1-The managers of the blood bank can avoid the high demand of blood products with the predicted low amount by announcing the exact need of blood products and reduce the waste costs.

2 - Accurate prediction of blood products by blood groups can reduce the cost of cross-wrist in emergencies.

Therefore, in this research, the researcher made efforts to implement the methodology of prediction of demand for blood products separately sorted by the blood groups by presenting an exact method for using the artificial neural networks as an important tool of data mining techniques. The general managing results of present results can be summarized as the following:

A. In the case of prediction of FFP blood product, the least and the most prediction error has been occurred for A^- and A^+ blood groups. So, the managers of the domain of blood product supply in the blood transfusion centers established in the centers of the provinces and the dependent centers on the provinces can estimate the change domain of error of the other blood groups in this blood product by regarding these two blood groups.

B. In the case of prediction of blood products of PLT, the least and most prediction error has occurred for O^- and A^+ blood groups. So, the planners of the domain of blood product supply can consider the change domain of error of other blood groups in this blood product by regarding these two blood groups.

C. In the case of prediction of RBC blood product, the least and most prediction error has occurred for A^- and A^+ blood groups. So, it can be said that the managers of the domain of blood product supply can evaluate the change domain of error of other blood groups in this blood product by regarding these two blood groups.

One of the most important applications of this research is to recognize the exact amount of patients' demand for different blood products separately sorted by different blood groups. This matter causes the appropriate measures to be taken in collecting the blood from the donators:

A. The mobile teams, semi- time and full-time fixed centers of blood collection and also the blood supply and blood transfusion

centers should collect appropriate amounts of blood groups from the donators so that a surplus or shortage of a blood group not to be created.
B. In donation by the apheresis method, the blood products can be collected accurately by the prediction of the type of required products so that the shortage or surplus of type of blood product not to be created.
The present research like any study had some limitations such as the restriction of the number of data existing in the research data set which has been limited to 30 months. About the artificial neural networks's demand for the higher number of data for appropriate learning, the amount of error calculated in the predictions was high, which should be regarded in the application of research results.

Competing Interests

The authors declare no competing interest

Authors' Contributions

The authors made equal contributions to the present study.

Acknowledge

I would like to express my special thanks of gratitude to all the individuals who collaborated with the research group. Undoubtedly, the execution of this research was impossible without the cooperation of these magnanimous staff.

References

1. Lin YK. System reliability evaluation for a multistate supply chain network with failure nodes using minimal paths. IEEE Transactions on Reliability. 2009 Mar; 58(1):34-40.
2. Uthayakumar R, Priyan S. Pharmaceutical supply chain and inventory management strategies: Optimization for a pharmaceutical company and a hospital. Operations Research for Health Care. 2013 Sep 1;2(3):52-64.
3. Privett N, Gonsalvez D. The top ten global health supply chain issues: perspectives from the field. Operations Research for Health Care. 2014 Dec 1;3(4):226-30.
4. Cobain TJ. Fresh blood product manufacture, issue, and use: A chain of diminishing returns? Transfusion medicine reviews. 2004 Oct 1;18(4):279-92.
5. Chapman JF, Hyam C, Hick R. Blood inventory management. Vox sanguinis. 2004 Jul; 87:143-5.
6. Fortsch SM, Khapalova EA. Reducing uncertainty in demand for blood. Operations Research for Health Care. 2016 Jun 1;9:16-28.
7. Aqmasheh S, Shamsasenjan K. The evaluation of blood crossmatches and blood utilization at university hospitals in Tabriz. The Scientific Journal of Iranian Blood Transfusion Organization (Khoon), 2017: 13(4).
8. Fasola FA, Shokubi WA. Audit of the red cell units supply of a busy hospital blood bank in Nigeria. Nigerian journal of clinical practice. 2009;12(2).
9. Williamson LM, Devine DV. Challenges in the management of the blood supply. The Lancet. 2013 May 25;381(9880):1866-75.
10. Mitra SB, Wu D, Holmes BN. An application of nanotechnology in advanced dental materials. The Journal of the American Dental Association. 2003 Oct 1;134(10):1382-90.
11. Maramazi Ghaflez B, Kaab Omeir H, Jalali Far M, Saki N, Torabizadeh Maatoghi J, Naderpour M. Study of rate and causes of blood components discard among Ahwaz's hospital. Sci J Iran Blood Transfus Organ. 2014; 11 (3):197-206.
12. Sadorsky P. Modeling and forecasting petroleum futures volatility. Energy Economics. 2006 Jul 1;28(4):467-88.
13. Dayhoff JE. Neural network architectures: an introduction. Van Nostrand Reinhold Co.; 1990 Jan 3.
14. Khanna T. Foundations of neural networks. Reading: Addison Wesley, 1990. 1990.
15. Du KL, Swamy MN. Independent component analysis. In Neural Networks and Statistical Learning 2014 (pp. 419-450). Springer, London.

Please cite this article as:

Ali asghar moslemi, Mahdi Yousefi Nejad attari. Prediction of demand for blood bank products according to blood groups by using artificial neural networks. Int J Hosp Res. 2021;10 (4).