

A predictive model for retention in specialized HIV/AIDS care

Modelo preditivo de retenção no cuidado especializado em HIV/aids

Modelo predictivo de retención en el cuidado especializado en VIH/SIDA

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Abstract

The establishment of universal targets for HIV/AIDS control and the implementation of treatment as prevention reinforce the need for on-going clinical follow-up of persons living with HIV/AIDS as an essential element of their care, where retention in care is both a need and a challenge. This study aimed to create a predictive model for retention of persons living with HIV/AIDS in health care. A decision tree statistical model was created, based on sociodemographic, clinical, and health behavior variables, identified in a database with information from 260 persons with HIV/AIDS, enrolled in a specialized treatment service. The model enabled the identification of nine variables with significant information gains in relation to the outcome variable, probable retention in health care, and the development of 24 decision rules, giving rise to a decision tree with 80.4% correct answers, which can help identify possible strategies to optimize retention and contribute to achieving the proposed targets for confronting the epidemic in the coming years.

Acquired Immunodeficiency Syndrome; Highly Active Antiretroviral Therapy; Delivery of Health Care; Decision Trees

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Introduction

Despite technical, scientific, and political strides in HIV/AIDS prevention, diagnosis, and treatment, an estimated 35 million infected individuals are unaware of their serological status, and approximately half of the persons diagnosed are not enrolled in any kind of health care service ^{1,2}.

In 2014, this scenario prompted the Joint United Nations Programme on HIV/AIDS (UNAIDS) to urge all countries to set targets aimed at maximizing the individual and collective benefits of HIV/AIDS diagnosis and treatment ^{3,4}.

The goal, known as 90-90-90, proposes to expand diagnosis and treatment so that 90% of PLWA (persons living with HIV/AIDS) are aware of their serological status, of these, 90% are using ART (antiretroviral therapy), and 90% of persons using specific drug therapy achieve viral suppression. To reach these goals, UNAIDS recommended expanding the start of treatment immediately after diagnosis, that is, rapid and sustained administration of ART with a view towards improved immune status and reduction of the risks of HIV transmission, progression to AIDS, and premature death ^{2,3,4,5}.

In order to achieve the goal and control the epidemic by 2030, pillars were defined to be monitored worldwide in order to identify the interventions' efficacy in each setting. These pillars represent the series of stages experienced by PLWA, from diagnosis of the infection to viral suppression (considered the ultimate objective of the continuum of care and treatment cascade). In Brazil, the cascade has three components, totaling the number of persons included in the provision of specific services in all the stages of: PLWA, persons diagnosed, enrolled in care, retained in health care, in use of ART, and with viral suppression. The latter is obtained with specific drug therapy ^{4,5,6}.

A PLWA is defined as retained in care when enrolled in an HIV care service, with continuous access to adequate care according to their health care needs and permanent follow-up by the service ⁶. Evidence indicates that this is a behavior that should be encouraged in PLWA in order to establish timely ART, reduce drug resistance and viral load, increase the CD4+ T lymphocyte count, improve clinical conditions, and increase survival ⁷.

Although retention is a priority in care for PLWA and an important pillar in the cascade of care, it is a challenge in Brazil and in the world. To improve retention requires a better understanding of barriers and facilitators, dealing with the origins in the individual patient, in the health services, and in the external environment ^{7,8,9}.

Retention of PLWA in health care is known to be essential for the epidemic to be controlled in the next two decades. The necessary consideration of local factors that impact retention in the cascade of care and the importance of equipping health professionals to encourage retention were the motivations for the current study, aimed at creating a predictive model for retention of PLWA in health care and intending to contribute to the identification of possible strategies to optimize retention of PLWA in care and to help achieve the goals.

To predict retention in care, the study analyzed the inherent conditions in the enrollment and permanence of persons with HIV/AIDS in follow-up, with the specialized outpatient service as the reference. The choice was based on the relevance of this service in the supply of activities targeted to follow-up of health conditions in PLWA and the service's impact on how these persons related to other services in the network of care.

Method

The study was designed to produce a decision tree, a statistical model using a data mining technique to classify the data, capable of leading the research to predict a target outcome with a view towards supporting the decision on this outcome ¹⁰.

The model enables the identification of independent variables, available in a database, consisting of decision variables that provide the basis for producing classification rules (text representations obtained from the model's structure), the graphic display of which produces a structure resembling an inverted tree ¹¹.

The tree thus consists of decision variables displayed hierarchically, starting from the root node (first variable), whose classification rules lead to internal nodes and their branches, towards an end

node with the decision. This is a low-cost resource that facilitates the data interpretation via graphic visualization with the potential to support health-related decisions^{10,11}.

To construct the model, variables were used from the study's database, *Dropout from Specialized Outpatient Clinical Follow-up of Persons Living with HIV/AIDS*¹², obtained from a secondary source (patient charts). The sample consisted of 260 AIDS cases, selected from a population of 1,941 adults recorded in the Brazilian Information System for Notifiable Diseases/AIDS (SINAN/AIDS) in the state of Paraíba, Brazil, from January 2007 to December 2013, all over 18 years of age and enrolled in the state's specialized outpatient referral clinic for clinical follow-up.

The sample size was set by sampling calculation for finite populations and the sample was collected by simple random sampling. Exclusion criteria were pregnant women and persons in detention or incarceration. Retention was defined from records on the patient chart pertaining to the individual's appearance at the clinic for consultation and/or tests, at a maximum interval of seven months. This period was defined according to the reasoning that clinically stable individuals would return for their clinical follow-up appointment within a maximum of six months, with one additional month added for cases that required rescheduling an appointment, according to the clinic's routine.

The decision tree was built using the Waikato Environment for Knowledge Analysis (Weka) package, version 3.7.8 (<https://www.cs.waikato.ac.nz/ml/weka/downloading.html>), and selection of variables from the database for inclusion in the model was based on variable's IG (information gain) in relation to the outcome variable (retention in health care). The IG was obtained by calculating the probability of decisions in the database set and in the subsets of independent variables related to the decision. Based on the numerical distribution of each variable's IG, the variables selected were those with the largest information gain in relation to the outcome. These variables were distributed hierarchically on the tree, in decreasing order of IG.

Based on the above-mentioned criteria, the following sociodemographic variables were included in the model: age (< 20 years, 20-39, 40-59, ≥ 60), marital status (single, married or in a stable union, separated/divorced/widow or widower), and residence in the same municipality as the outpatient service conducting the follow-up (yes, no). The lifestyle variables and associated health problems included in the model were: sexual orientation (homosexual, heterosexual, bisexual, or information not recorded on the patient chart) and alcohol use (yes, no). The clinical variables were: in use of ART (yes, no), result of last viral load test (undetectable, detectable, not performed), hospitalizations at the service (yes, no), and number of pills (ART) taken per day (< 4; ≥ 4).

The variables from the database that did not obtain a significant IG and were thus not included in the model, although the literature suggests their relationship to retention in care, were: sex, race, schooling, illegal drug use, time since diagnosis, and presence of chronic diseases.

The study complied with the ethical guidelines for research in human subjects, as specified in *Resolution n. 466/2012*, including approval by the Institutional Review Board, of the Federal University of Paraíba (UFPB), under case review CAAE 41019115.7.0000.5188/2015.

Results

The study showed an overall retention rate of 68.5%. The sample was predominantly male (64.6%), single (45%), heterosexual (69.3%), with age ranging from 18 to 71 years and a mean of 42.3 years, predominantly in the 20-39-year bracket (60.4%). Only 37.7% lived in the same municipality as the health service responsible for the follow-up; 92.3% of users were in ART, 91.2% presented a detectable viral load (VL) at the start of outpatient clinical follow-up; 65% had an undetectable VL at the last test; and 53.1% were taking more than four pills a day.

The decision tree (Figure 1) showed 80.4% correct answers and the capacity to correctly classify 209 individuals according to the decision matrix (Table 1), presenting correct answers along the main diagonal and the errors identified outside of it.

Validation measures were also used to check the model's quality (Table 2), the results of which showed good sensitivity (approximately 80%) for identifying individuals with probability of non-retention in care and positive likelihood ratio, indicating that the odds of identifying likely non-

retention in care is four times higher when the model is applied. These results were the basis for the model's validity in predicting the target outcome.

The tree allowed establishing 24 decision rules (Box 1) for the study sample. This highlights the variables' importance as decisive for predicting retention of PLWA in health care.

The variables closest to the tree's root or main node were those with the highest IG. This means that their results lead to greater or lesser likelihood of the outcome occurring. Thus, "use of ART" was the variable with the highest information gain, constituting the tree's main node, branching to the internal nodes (formed by the other variables) and the leaves that contain the decision variable – likely versus unlikely retention in health care.

To illustrate the model's applicability, its rules were applied to a clinical case (Box 2).

Discussion

The study's sociodemographic profile corroborates the epidemiological pattern of HIV infection in Brazil and the world and indicates the predominance of males and heterosexuals^{5,8,13}.

Although gender was not considered in the model as a significant variable for predicting retention, an analysis of the proportion, by gender, in the study scenario (ratio of 1.8:1, i.e., 18 men for every ten women) corroborates the results of a study in another state of Northeast Brazil, reaffirming the increase in the number of cases in women, which the literature attributes to the increase in heterosexual transmission, among other factors¹⁴.

As for age bracket, studies have suggested higher likelihood of retention with increasing age, since for every additional year in age, the risk of non-retention in care decreases by 4 to 5%. According to the model, younger individuals (under 20 years) run higher risk of non-retention, which the literature suggests may be due to the fact that young people experience greater difficulty in adapting their lifestyle to the new reality required by treatment, with changes in eating habits, the routine of taking medications, and other psychological issues related to living with the infection^{12,15,16,17}.

As for marital status, a study in Santa Maria, Rio Grande do Sul State, Brazil, suggests that single individuals are more prone to ART dropout, considering the associations with social isolation, lack of social support, and treatment dropout in general¹⁸. Considering the intersection between ART adherence and retention in care, this result would contradict what the model proposes.

However, a study in Rio de Janeiro that specifically involved a male population (the predominant gender in the current study) mentions that in cases where serological status is undisclosed, having more persons residing in the same household can hinder regular taking of medications¹⁹. This finding could explain the higher retention of single and separated males and widowers in the model, considering the likelihood of these individuals living with fewer persons in the household and the close relationship between ART adherence and retention in care. However, other studies are needed to elucidate this issue and the factors that influence higher retention by these groups, regardless of disclosure of their serological status.

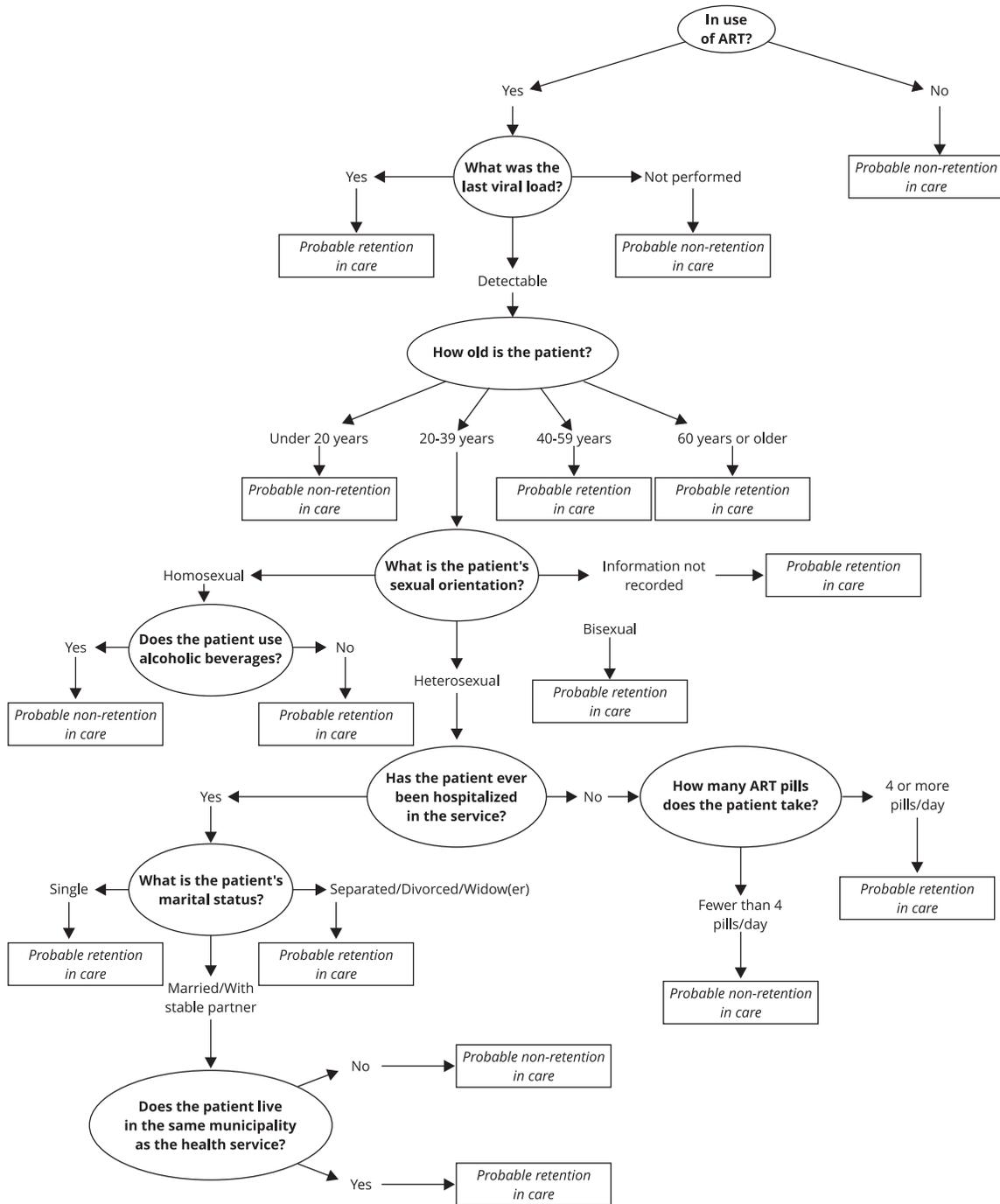
As for place of residence, the prevalence of individuals residing in other municipalities not only expresses the phenomenon of interiorization of HIV/AIDS in the state of Paraíba, but also calls attention to the negative influence of geographic barriers on the follow-up of health status in these individuals. It is known that the increase in infection in smaller, lower-income municipalities includes financial, housing, and transportation problems experienced by the inhabitants. These difficulties are further aggravated when the individual needs to travel away from home to obtain access to ART, follow-up appointments, and specific tests^{16,20,21}, which can compromise retention in outpatient care, as indicated by the model.

As for lifestyle variables and related health problems, individuals with a history of alcohol use (abusive or otherwise) are known to have higher odds of non-adherence to ART and non-retention in care^{16,18}.

As for clinical variables, the model highlighted ART use as having the highest information gain for retention. According to a previous study¹¹, the risk of likely non-retention decreases by approximately 61% when individuals are in ART. This reaffirms the close relationship between these two pillars in the cascade of care¹³. Considering that the Brazilian Ministry of Health currently recommends

Figure 1

Predictive decision tree for retention in health care of persons living with HIV/AIDS. João Pessoa, Paraíba State, Brazil, 2016.



ART: antiretroviral therapy.

Note: The tree's root is the use of ART.

Table 1

Decision matrix for retention in care of persons living with HIV/AIDS. João Pessoa, Paraíba State, Brazil, 2016.

	Classification of decision tree			Total
	Retention in care	Probable non-retention	Probable retention	
Classification of sample (real)	Non-retention	43 *	39	82
	Retention	12	166 *	178
	Total	55	205	260
Total correct answers				80.4%

* Main diagonal containing the model's correct answers, totaling 209 (80.4%) individuals classified correctly.

Table 2

Measures of validation of the decision tree model.

Model's quality		95%CI
Accuracy	80.4%	75.6; 85.2
Sensitivity	78.2%	67.3; 89.1
Specificity	81.0%	75.6; 86.3
Pretest probability	21.2%	16.2; 26.1
Positive predictive value	52.4%	41.6; 63.2
Negative predictive value	93.3%	89.6; 96.9
Positive likelihood ratio	4.1	-
Negative likelihood ratio	0.3	-

95%CI: 95% confidence interval.

initiating ART immediately after diagnosis, regardless of CD4+ T lymphocyte count, knowing the interrelationship between ART adherence and retention in care^{4,5} and implications for inadequate retention and adherence for individual and population-based results¹³, this study's identification of 92.3% adherence to ART and only 68.5% retention in care emphasizes the need for interventions capable of improving retention.

The model showed that individuals whose last viral load was undetectable tended to be retained in care. For this variable, there was an increase in the percentage of individuals with undetectable viral load, from the start of treatment (8.8%) to the most recent viral load test (65%), which can be attributed to adequate use of ART. Although positive, this percentage is still insufficient to reach the 90-90-90 targets.

According to the study, the use of four or more pills a day contributed to retention in care. Reporting on the interrelationship between ART and retention in care, as mentioned previously, this finding contradicts some studies that suggest that the more medications in the treatment regimen, the lower the adherence and thus the lower the retention in care^{8,19,22}.

This emphasizes the need for more frequent follow-up of drug-drug interactions and side effects when the regimen contains more pills, a possible contributing factor to closer contact between users and the service responsible for their clinical management¹⁵ and retention, in case the service is active from this perspective. The team should thus value care with the expectation of simplifying the regimens and supporting the adaptations to the routine, which requires closer linkage between the health service and PLWA to strengthen retention^{23,24,25}.

Box 1

Decision rules based on the decision tree: the variable is the necessary condition (IF) and the decision (THEN) is the result obtained with the decision variable. João Pessoa, Paraíba State, Brazil, 2016.

Attribute	Decision
1. IF patient is not using ART	THEN retention in care is unlikely
2. IF patient is using ART	THEN it will be necessary to verify last viral load
3. IF patient is using ART and the last viral load is undetectable	THEN retention in care is likely
4. IF patient is using ART and there has been no viral load test	THEN retention in care is unlikely
5. IF patient is using ART and the last viral load is detectable	THEN it will be necessary to verify patient's age
6. IF patient is using ART and the last viral load is detectable and the patient is less than 20 years old	THEN retention in care is unlikely
7. IF patient is using ART and the last viral load is detectable and the patient is 40-59 years old	THEN retention in care is likely
8. IF patient is using ART and the last viral load is detectable and the patient is 60 years or older	THEN retention in care is likely
9. IF patient is using ART and the last viral load is detectable and the patient is 20-39 years old	THEN it will be necessary to verify the patient's sexual orientation
10. IF patient is using ART and the last viral load is detectable, the patient is 20-39 years old and homosexual	THEN it will be necessary to verify whether the patient uses alcoholic beverages
11. IF patient is using ART and the last viral load is detectable, the patient is 20-39 years old, homosexual, and uses alcoholic beverages	THEN retention in care is unlikely
12. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old, homosexual and does not use alcoholic beverages	THEN retention in care is likely
13. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old and bisexual	THEN retention in care is likely
14. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old and there is no information on sexual orientation	THEN retention in care is likely
15. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old and heterosexual	THEN it will be necessary to verify whether the patient has been hospitalized in the service
16. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old, heterosexual and has been hospitalized in the service	THEN it will be necessary to verify the patient's marital status
17. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old, heterosexual, has been hospitalized in the service, and single marital status	THEN retention in care is likely
18. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old, heterosexual, has been hospitalized in the service, and marital status is separated/widow(er)	THEN retention in care is likely
19. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old, heterosexual, has been hospitalized in the service, marital status is married or in stable union	THEN it will be necessary to verify whether the patient lives in the same municipality as the service
20. IF patient is using ART and the last viral load is detectable, patient is 20-39 years old, heterosexual, has been hospitalized in the service, marital status is married or in a stable union, and lives in the same municipality as the service	THEN retention in care is likely
21. IF patient is using ART and the last viral load is detectable, the patient is 20 to 39 years old, heterosexual, has been hospitalized in the service, marital status is married or in a stable union, and does not live in the same municipality as the service	THEN retention in care is unlikely
22. IF patient is using ART and has detectable viral load, patient is 20-39 years old, heterosexual, and has never been hospitalized in the service	THEN it will be necessary to verify how many pills per day the patient is taking
23. IF patient is using ART and has detectable viral load, patient is 20-39 years old, heterosexual, has never been hospitalized in the service, and takes fewer than 4 pills/day in ART	THEN retention in care is unlikely
24. IF patient is using ART and has detectable viral load, patient is 20-39 years old, heterosexual, never been hospitalized in the service, and takes 4 or more pills/day	THEN retention in care is likely

ART: antiretroviral therapy.

Source: elaborated by the authors.

Box 2

Application of rules extracted from decision tree.

Clinical case	Application of the model
<p>Male patient, 19 years old, homosexual. At time of reporting, patient presented some clinical manifestations, was in antiretroviral therapy, taking 2 pills a day, and last viral load, 3 months ago, was detectable. No previous hospitalizations in the service. Given this context, what will the patient's behavior be in follow-up/retention in the service/network of care?</p>	<p>The decision variables in the tree are arranged hierarchically, starting from the root node (first variable). In this model it is represented by the variable ART use. Starting interpretation from rule 2: IF patient is using ART, THEN it will be necessary to verify the last viral load. Since the last viral load was detectable, analyze rule 5: IF patient is using ART and the last viral load is detectable, THEN it will be necessary to verify the patient's age. Since the patient is 19 years old, rule 6 will be used: IF patient is using ART and the last viral load is detectable and the patient is less than 20 years old, THEN retention in care is unlikely.</p>

ART: antiretroviral therapy.

Source: elaborated by the authors.

The retention rate of 68.5% was higher than the Brazilian national average, which is 66% (among 83% of HIV-positive diagnosed individuals), according to the country's latest HIV/AIDS epidemiological bulletin ^{4,13}. This scenario underscores the relevance of planning activities and local strategies capable of improving all the pillars in the cascade of care, especially those related to ART adherence and retention in care to achieve the targets ^{26,27}. Early identification of triggering factors for retention and non-retention is essential for health professionals in the specialized service to act by maximizing facilitators of retention and reducing barriers ²⁸.

It is important to extend the care provided by the health care team to include the patients' families, considering their role in this context as a motivator for PLWA to proceed with treatment and improve their quality of life ²⁹.

Final remarks

Retention in health care for PLWA has gained attention thanks to the cascade of continuing care, so it is important to know the factors that help promote retention in order to achieve the goals of controlling the epidemic.

Despite the study's difficulties in approaching the topic of "retention" in the Brazilian literature for discussion of the results in the Brazilian reality, the close relationship between this theme, and other inherent phenomena in treatment and care of PLWA (such as the health team-patient bond and adherence to treatment and care), the findings indicate that retention in care is influenced by sociodemographic factors, lifestyle, and clinical variables, which merit attention in order to promote effective intervention by health services in promoting retention.

In this sense, the decision tree created here is a model that can support health professionals at the specialized service to identify aspects by which it is possible to intervene in the bond and retention (follow-up) of PLWA, supporting the identification and planning of interventions to prevent non-retention. For example, the model can be used in nursing consultations to improved nursing care as an important component of this specialized care as a whole.

A limitation to the study, for purposes of generalization, was the fact that the sample came from a single service, although this service is the reference for specialized HIV/AIDS care in the state of Paraíba. Other limitations include the use of a secondary data source, where the richness of the results depends on the records' quality, and the fact that the model did not consider inherent aspects of the service's organization.

Thus, considering the importance of retention in care in the coming years, especially for reaching the UNAIDS targets for controlling the epidemic, other studies are needed on individual, social, and programmatic variables to produce a wider picture of factors involved in retention in care for persons living with HIV/AIDS.

Contributors

W. A. Miranda worked on the study's conception and design, data interpretation, and writing and discussion of the article. L. B. Medeiros worked on the study design, data analysis and interpretation, final revision, and approval of the version for publication. O. D. C. P. Leadebal worked on the study conception and design, methodology, and final version. J. A. Nascimento and K. S. Q. S. Ribeiro worked on the final version and approval for publication. J. A. Nogueira worked on the critical revision, final version, and approval for publication.

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Resumo

O estabelecimento de metas universais voltadas ao controle do HIV/aids e a instituição do tratamento como forma de prevenção reforçam a necessidade do acompanhamento clínico continuado das pessoas vivendo com HIV/aids como um elemento indispensável ao cuidado destas, sendo a retenção no cuidado em saúde uma necessidade e um desafio. Neste estudo, objetivou-se construir um modelo preditivo de retenção de pessoas vivendo com HIV/aids no cuidado em saúde. Para tanto foi construído um modelo estatístico, árvore de decisão, com base em variáveis sociodemográficas, clínicas e relacionadas aos comportamentos em saúde, identificadas em um banco de dados que contemplava informações de 260 pessoas com HIV/aids, vinculadas a um serviço especializado no atendimento a estes indivíduos. O modelo subsidiou a identificação de nove variáveis cujos ganhos de informação foram significativos em relação à variável desfecho, provável retenção no cuidado em saúde, e à construção de 24 regras de decisão, dando origem a uma árvore com percentual de acerto de 80,4%, as quais poderão contribuir com a identificação de possíveis estratégias no sentido de otimizar a retenção e contribuir com o alcance das metas propostas para o enfrentamento da epidemia nos próximos anos.

Síndrome de Imunodeficiência Adquirida; Terapia Antirretroviral de Alta Atividade; Assistência à Saúde; Árvores de Decisões

Resumen

El establecimiento de metas universales dirigidas al control del VIH/SIDA, y la institución del tratamiento como forma de prevención, refuerzan la necesidad del seguimiento clínico continuado de las personas que viven con VIH/SIDA, como un elemento indispensable para el cuidado de estas, siendo la retención en el cuidado de salud una necesidad y un desafío. En este estudio, el objetivo fue construir un modelo predictivo de retención de personas viviendo con VIH/SIDA dentro del ámbito del cuidado en salud. Para tal fin, se construyó un modelo estadístico, un diagrama de árbol de decisión, en base a variables sociodemográficas, clínicas, y aquellas relacionadas con los comportamientos en salud, identificadas en un banco de datos que contemplaba información de 260 personas con VIH/SIDA, vinculadas a un servicio especializado en la atención a estos individuos. El modelo subsidió la identificación de nueve variables, cuyos réditos respecto a información fueron significativos en relación con la variable desenlace, probable retención en el cuidado en salud, y a la construcción de 24 reglas de decisión, dando origen a un árbol con un porcentaje de acierto de un 80,4%, que podría contribuir a la identificación de posibles estrategias, en el sentido de optimizar la retención y contribuir al alcance de las metas propuestas para enfrentar la epidemia en los próximos años.

Síndrome de Inmunodeficiencia Adquirida; Terapia Antirretroviral Altamente Activa; Prestación de Atención de Salud; Árboles de Decisión

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