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PREDICTION MODEL FOR DELAYED FOLLOW-UP VISITS AMONG GERIATRIC PATIENTS AFTER HOSPITAL DISCHARGE BASED ON DIGITAL HEALTH LITERACY, FAMILY SUPPORT, AND MEDICATION REGIMEN COMPLEXITY AT A HOSPITAL IN MEDAN CITY

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ABSTRACT

Delayed post-discharge follow-up among geriatric patients may compromise continuity of care and increase the risk of adverse health outcomes. Early identification of patients at high risk is essential to facilitate timely interventions. This study aimed to develop and validate a prediction model for delayed follow-up visits among hospitalized geriatric patients. A cross-sectional study was conducted among 263 geriatric patients discharged from a general hospital in Medan, Indonesia. Digital health literacy, family support, and medication regimen complexity were assessed using validated instruments. Multivariable logistic regression was performed to identify independent predictors of delayed follow-up, and model performance was evaluated using the area under the receiver operating characteristic curve (AUROC) and the Hosmer–Lemeshow goodness-of-fit test. Delayed post-discharge follow-up occurred in 34.6% of participants. Low digital health literacy (adjusted OR = 2.87), poor family support (adjusted OR = 1.93), and high medication regimen complexity (adjusted OR = 3.76) were independently associated with delayed follow-up. The final prediction model demonstrated good discrimination with an AUROC of 0.821 (95% CI: 0.769–0.873) and satisfactory calibration (Hosmer–Lemeshow p = 0.617), indicating good predictive performance. Low digital health literacy, poor family support, and high medication regimen complexity are significant predictors of delayed post-discharge follow-up among geriatric patients. The proposed prediction model may serve as a practical screening tool to identify patients requiring targeted discharge planning and transitional care interventions, thereby improving continuity of care and supporting healthy ageing.

Keywords: *Geriatric patients, delayed follow-up, digital health literacy, family support, prediction model.*

INTRODUCTION

The older adult population in Indonesia has continued to increase alongside improvements in life expectancy resulting from advances in health development. This demographic transition has contributed to a higher prevalence of degenerative and chronic diseases that require continuous and long-term healthcare services. Population ageing has also become a global concern, with the number of individuals aged 60 years and older projected to reach 2.1 billion worldwide by 2050. This trend highlights the urgent need for healthcare systems to become more responsive to the complex needs of older populations (Giehl et al., 2024; Setiati et al., 2024).

Geriatric patients commonly present with complex clinical conditions characterized by multimorbidity, age-related physiological decline, and the concurrent use of multiple medications. These characteristics necessitate comprehensive and multidisciplinary care, including appropriate monitoring after hospital discharge. Adherence to scheduled

follow-up visits is therefore an important indicator of continuity of care and successful post-discharge management. In Indonesia, hospital readmission rates among older patients have been reported to range from 18.1% to 36.3% (Setiati et al., 2024). Delayed follow-up visits may postpone clinical evaluation, contribute to deterioration in health status, increase the risk of unplanned readmission, and impose additional burdens on healthcare resources.

Previous studies have identified several factors associated with hospital readmission among geriatric patients, including nutritional status, depression, length of hospital stay, and comorbidities (Kara et al., 2026; Toporowski et al., 2026). However, studies that simultaneously examine digital health literacy, family support, and medication regimen complexity as predictors of delayed follow-up visits remain limited. These three factors are particularly relevant because they may influence patients' ability to understand post-discharge instructions, maintain treatment adherence, access healthcare information, and attend scheduled follow-up appointments.

Digital health literacy has become increasingly important with the growing integration of information and communication technologies into healthcare delivery. It refers to an individual's ability to access, understand, evaluate, and apply health information obtained through digital platforms to support appropriate health-related decisions. Among older adults, limited digital health literacy may reduce the effective use of online health information, digital appointment systems, and technology-based healthcare services. Previous studies have shown that digital health literacy is positively associated with health-promoting behaviors, self-efficacy, and self-care competence among older populations (Ağan et al., 2026; Happe et al., 2026). Nevertheless, older adults remain one of the groups most vulnerable to digital exclusion because of limited technological skills, difficulties in evaluating the credibility of online information, and unequal access to digital resources (Giehl et al., 2024; Kachentawa, 2024).

Family support is another essential factor in maintaining continuity of care among geriatric patients after hospital discharge. Family members commonly act as caregivers, reminders, motivators, and facilitators who assist patients in following treatment instructions and attending scheduled healthcare visits. Such support may include instrumental, emotional, informational, and appraisal assistance throughout the recovery process. Evidence indicates that adequate family support contributes to better health management and more holistic care practices among older adults (Kaya et al., 2026). In contrast, insufficient family involvement may increase the likelihood of missed appointments, poor treatment adherence, and fragmented care during the transition from hospital to home.

Medication regimen complexity may also influence patients' ability to comply with post-discharge care. Geriatric patients frequently experience multimorbidity and are therefore commonly exposed to polypharmacy, which is generally defined as the concurrent use of five or more medications (Febriyanti et al., 2023; Lu et al., 2024). Complex regimens involving multiple dosage forms, frequent administration schedules, and special instructions may create substantial difficulties for older patients and their

caregivers. The Medication Regimen Complexity Index has been widely used to assess these dimensions and has been associated with medication-related problems and hospitalization risk (Lu et al., 2024; Poojar et al., 2024). Consequently, highly complex treatment regimens may not only compromise medication adherence but also contribute to delayed follow-up visits and poorer continuity of care.

Given the potential influence of these factors, an integrated prediction model is needed to identify geriatric patients at high risk of delayed follow-up after hospitalization. Therefore, this study aimed to develop a prediction model based on digital health literacy, family support, and medication regimen complexity among geriatric patients treated at a hospital in Medan. The proposed model is expected to assist healthcare professionals in conducting early risk screening before discharge and in planning targeted interventions for vulnerable patients. Ultimately, the implementation of such a model may improve adherence to follow-up care, reduce unplanned readmissions, and strengthen the quality of post-discharge geriatric care in Indonesia.

RESEARCH METHOD

This prospective cohort study was conducted at a hospital in Medan from January to December 2025 to develop a prediction model for delayed post-discharge follow-up among geriatric patients. Eligible participants were patients aged 60 years or older, hospitalized for at least 48 hours, and willing to provide informed consent (Giehl et al., 2024). Patients with severe cognitive impairment that precluded interviews, terminal illness or a life expectancy of less than six months, or no available family member or caregiver were excluded (Setiati et al., 2024; Urquiza et al., 2025). Participants were recruited through consecutive sampling, with a minimum target of 250 patients based on multivariable logistic regression requirements and findings from a previous study involving 235 participants with a 32.3% readmission rate (Setiati et al., 2024).

The primary predictors were digital health literacy, family support, and medication regimen complexity. Digital health literacy was assessed at discharge using the eight-item HLS19-DIGI, which evaluates access, understanding, appraisal, and application of digital health information and has demonstrated high reliability in older populations (Cronbach's $\alpha = 0.976$) (Liu et al., 2024; Giehl et al., 2024). Family support was measured through a 15-item questionnaire administered to the primary caregiver, covering instrumental, emotional, informational, and appraisal support, as adapted from Kaya et al., (2026). Medication complexity was evaluated using the validated Medication Regimen Complexity Index, which considers dosage forms, administration frequency, and special instructions (Lu et al., 2024; Poojar et al., 2024). Delayed follow-up was defined as attendance more than seven days after the scheduled post-discharge visit (Setiati et al., 2024). Demographic and predictor data were obtained through structured interviews, while clinical information, including diagnosis, length of stay, medication count, and comorbidities, was extracted from medical records (Kara et al., 2026; Lu et al., 2026; Toporowski et al., 2026).

Instrument validity and reliability were evaluated in a pilot sample of 30 respondents with characteristics similar to those of the main study population; Cronbach's α values were 0.976 for HLS19-DIGI and 0.857 for the family support questionnaire (Liu et al., 2024). Data analysis included univariable descriptive analysis, bivariate analysis using the chi-square test for categorical variables and the independent-samples t test or Mann–Whitney test for continuous variables, and multivariable logistic regression (Setiati et al., 2024). Variables with $p < 0.25$ in bivariate analysis were entered into a backward stepwise model, with model selection based on statistical significance and the Akaike Information Criterion (Setiati et al., 2024; Urquiza et al., 2025). Internal validation was performed using 1,000 bootstrap resamples. Model discrimination was assessed using the area under the receiver operating characteristic curve, while calibration was evaluated using the Hosmer–Lemeshow test (Setiati et al., 2024). Analyses were conducted using IBM SPSS version 26 and RStudio version 4.2.2. Ethical approval was obtained from the Health Research Ethics Committee of the participating hospital before data collection (Giehl et al., 2024).

RESULT AND DISCUSSION

Result

Participant Characteristics

A total of 263 geriatric patients were included in the analysis, with a participation rate of 95.8%. The mean age was 67.91 years, and 54.2% of participants were female. Most participants had primary education or lower (42.6%), while circulatory system diseases were the most common primary diagnosis (38.4%). The mean length of hospital stay was 8.4 days, and the mean number of prescribed medications was 6.7; polypharmacy was identified in 71.2% of participants. The demographic and clinical characteristics of the study population are presented in Table 1.

Table 1. Demographic and clinical characteristics of the study participants (N = 263)

Characteristic	n (%) or Mean (Range)
Age, years	67.91
Female	143 (54.2)
Male	120 (45.8)
Primary education or lower	112 (42.6)
Higher education	48 (18.3)
Laborer or farmer	90 (34.2)
Civil servant or private-sector employee	75 (28.5)
Self-employed or unemployed	98 (37.3)
Circulatory system disease	101 (38.4)
Endocrine system disease	64 (24.3)
Respiratory system disease	49 (18.6)
Length of hospital stay, days	8.4 (3–21)
Number of medications	6.7 (2–15)
Polypharmacy, ≥5 medications	187 (71.2)

Distribution of Predictor Variables

Low digital health literacy was observed in 58.2% of participants, whereas only 14.4% demonstrated high digital health literacy. Good family support was reported by 52.8% of participants, while 47.2% received poor family support. High medication regimen complexity was identified in 63.5% of the study population. The distribution of the three predictor variables is presented in Figure 1.

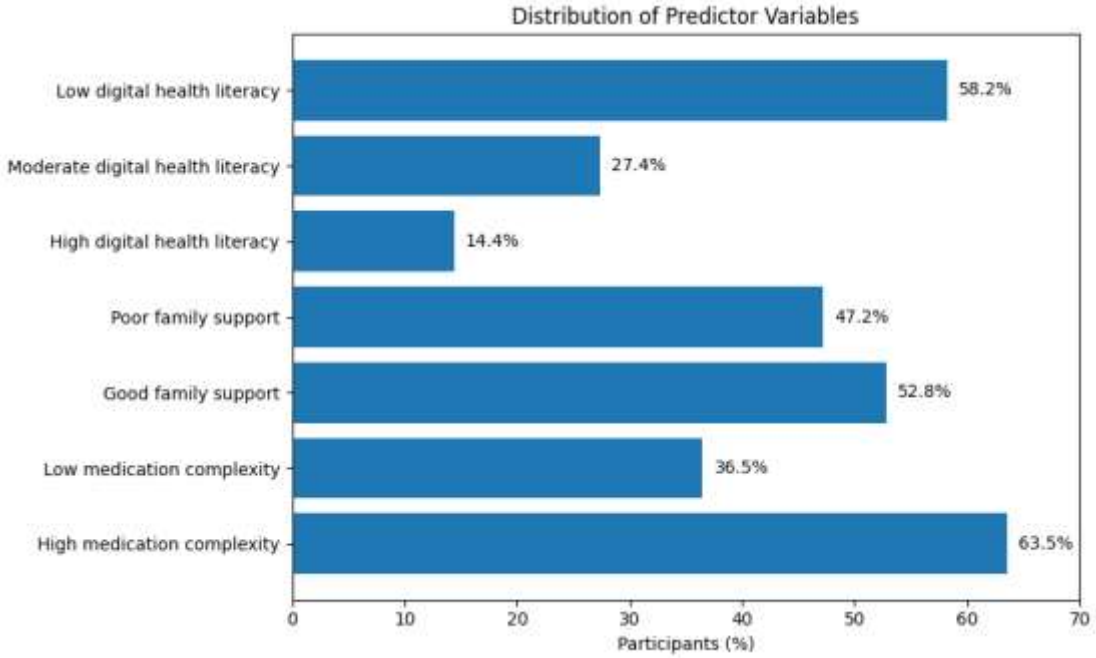

Figure 1. Distribution of digital health literacy, family support, and medication regimen complexity among the study participants**.**

As shown in Figure 1, low digital health literacy and high medication regimen complexity were the most prevalent characteristics among the participants, affecting more than half of the study population. In contrast, family support was relatively balanced, with a slightly higher proportion of participants reporting good family support than poor family support.

Delayed Follow-up Outcome

Delayed post-discharge follow-up was observed in 91 of the 263 participants (34.6%). The mean delay beyond the scheduled follow-up appointment was 14.3 days. The distribution of follow-up status among the study participants is presented in Table 2.

Table 2. Distribution of delayed post-discharge follow-up among study participants (N = 263)

Follow-up outcome	n	%
Delayed follow-up	91	34.6
Timely follow-up	172	65.4
Total	263	100.0

Approximately one-third of the participants experienced delayed follow-up after hospital discharge, indicating that delayed attendance at scheduled outpatient visits was relatively common in this study population.

Bivariate Analysis

Bivariate analysis showed that all three predictor variables were significantly associated with delayed post-discharge follow-up (Table 3). Patients with low digital health literacy were 3.2 times more likely to experience delayed follow-up than those with high digital health literacy ($p < 0.001$). Similarly, poor family support was associated with a 2.1-fold higher risk of delayed follow-up ($p = 0.003$), whereas patients with high medication regimen complexity had a 4.3-fold greater risk than those with low medication regimen complexity ($p < 0.001$).

Table 3. Bivariate analysis of factors associated with delayed post-discharge follow-up

Variable	Category	Crude OR	95% CI	p-value
Digital health literacy	Low vs. High	3.20	–	<0.001
Family support	Poor vs. Good	2.10	–	0.003
Medication regimen complexity	High vs. Low	4.30	–	<0.001

The strongest association with delayed follow-up was observed for medication regimen complexity, followed by digital health literacy and family support. These variables were subsequently included in the multivariable logistic regression analysis.

Multivariable Logistic Regression Analysis

Variables that showed statistical significance in the bivariate analysis were entered into the multivariable logistic regression model. As presented in Table 4, digital health literacy, family support, and medication regimen complexity remained independent predictors of delayed post-discharge follow-up.

Table 4. Multivariable logistic regression model for delayed post-discharge follow-up

Variable	Adjusted OR	95% CI	p-value
Low digital health literacy	2.87	1.92–4.28	<0.001*
Poor family support	1.93	1.31–2.85	0.001*
High medication regimen complexity	3.76	2.48–5.69	<0.001*

**Statistically significant at $p < 0.05$.*

Among the three predictors, medication regimen complexity showed the strongest association with delayed follow-up (adjusted OR = 3.76), followed by low digital health literacy (adjusted OR = 2.87) and poor family support (adjusted OR = 1.93). These findings indicate that all three variables independently contributed to the prediction of delayed post-discharge follow-up in geriatric patients.

Model Performance

The predictive performance of the final logistic regression model was evaluated using discrimination and calibration analyses. As presented in Table 5, the model demonstrated good discriminative ability, with an area under the receiver operating characteristic curve (AUROC) of 0.821 (95% CI: 0.769–0.873). The Hosmer–Lemeshow goodness-of-fit test indicated adequate model calibration ($\chi^2 = 6.27$, $p = 0.617$). At the optimal probability threshold, the model achieved a sensitivity of 79.1%, specificity of 74.4%, positive predictive value of 62.3%, negative predictive value of 87.1%, and an overall classification accuracy of 76.0%. The ROC curve illustrating the discriminative performance of the model is presented in Figure 2.

Table 5. Performance of the prediction model for delayed post-discharge follow-up

Performance measure	Value
AUROC (95% CI)	0.821 (0.769–0.873)
Hosmer–Lemeshow χ^2	6.27
Hosmer–Lemeshow p-value	0.617
Sensitivity (%)	79.1
Specificity (%)	74.4
Positive Predictive Value (%)	62.3
Negative Predictive Value (%)	87.1
Overall Accuracy (%)	76.0

The performance metrics indicate that the prediction model had good discrimination and satisfactory calibration. The relatively high negative predictive value suggests that the model was effective in identifying patients who were unlikely to experience delayed follow-up.

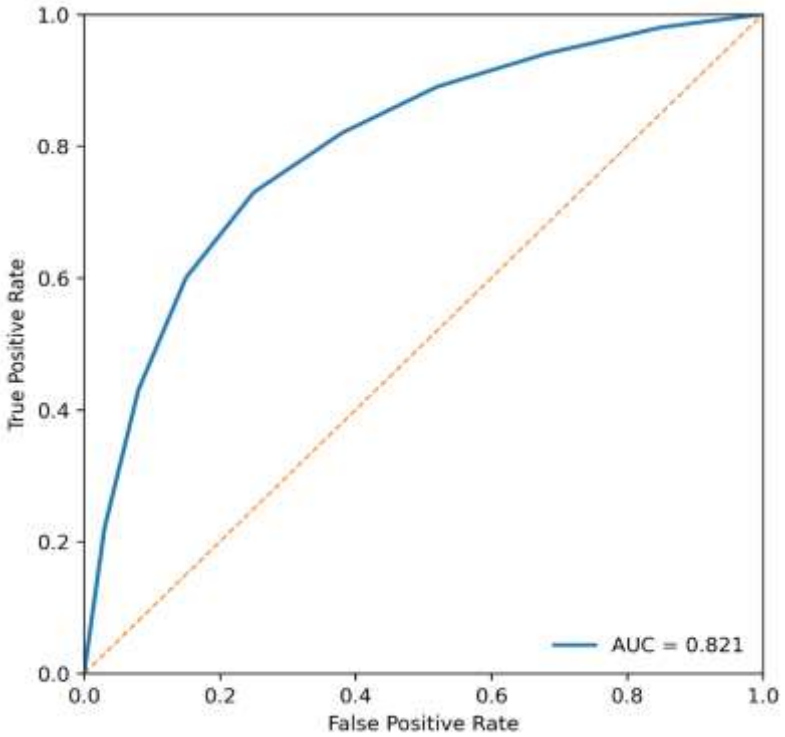

Figure 2. Receiver operating characteristic (ROC) curve of the final prediction model.

The ROC curve (Figure 2) demonstrates good discriminative performance, with an AUROC of 0.821, indicating that the model has a good ability to distinguish between patients who experienced delayed follow-up and those who attended their scheduled follow-up on time.

Clinical Interpretation of the Prediction Model

The final prediction model identified three independent predictors of delayed post-discharge follow-up among geriatric patients: low digital health literacy, poor family support, and high medication regimen complexity. Among these variables, medication regimen complexity demonstrated the strongest predictive effect, followed by digital health literacy and family support. Collectively, these predictors contributed to good model discrimination and calibration, supporting their usefulness in identifying patients at increased risk of delayed follow-up.

The model may be applied as a practical screening tool before hospital discharge to assist healthcare professionals in stratifying patients according to their risk of delayed follow-up. Patients identified as high risk may benefit from targeted interventions, including medication counseling, caregiver engagement, and digital health education, to improve adherence to scheduled follow-up visits and promote continuity of care.

Discussion

The present study identified that 34.6% of geriatric patients experienced delayed post-discharge follow-up, indicating that delayed attendance at scheduled outpatient visits

remains a substantial challenge in transitional care. This proportion is comparable to the 30-day readmission rates reported among hospitalized older adults in Indonesia and other countries, suggesting that continuity of care after discharge remains a global concern (Setiati et al., 2024; Urquiza et al., 2025). Furthermore, low digital health literacy was independently associated with delayed follow-up, with patients having low digital health literacy nearly three times more likely to miss their scheduled visit. This finding supports previous evidence demonstrating that individuals with adequate digital health literacy are better able to obtain, understand, evaluate, and apply health information, thereby improving treatment adherence and self-management (Liu et al., 2024; Giehl et al., 2024). Similarly, Huang et al. (2026) reported that higher eHealth literacy among older adults was associated with healthier behaviors and improved adherence to chronic disease management.

Family support and medication regimen complexity were also identified as significant predictors of delayed follow-up. Patients receiving poor family support had almost twice the risk of delayed follow-up, consistent with previous studies showing that family members play an essential role in reminding, motivating, and assisting older adults during recovery after hospitalization (Kaya et al., 2026; Sawadogo et al., 2026). Likewise, medication regimen complexity emerged as the strongest predictor in the model, highlighting the challenges of polypharmacy among geriatric patients. Previous studies have demonstrated that higher Medication Regimen Complexity Index (MRCI) scores are associated with adverse drug events, hospitalization, and medication-related problems (Poojar et al., 2024; Raboti et al., 2026). These findings are further supported by evidence showing that inappropriate polypharmacy remains highly prevalent among older adults with multiple chronic conditions (Febriyanti et al., 2023), emphasizing the importance of medication review during care transitions.

A major strength of this study is the integration of digital health literacy, family support, and medication regimen complexity into a single prediction model for delayed post-discharge follow-up. Previous prediction models have primarily focused on demographic characteristics, comorbidities, functional decline, or clinical indicators of readmission risk (Setiati et al., 2024; Urquiza et al., 2025). In contrast, the present study incorporates behavioral, social, and pharmacotherapy-related determinants that are directly modifiable through clinical intervention. This broader perspective reflects the multidimensional nature of geriatric care and provides a more comprehensive approach to identifying patients who require additional support after hospital discharge.

Another important contribution of this study is the development of a prediction model with good discrimination (AUROC = 0.821), demonstrating its potential application as a practical screening tool before discharge. Unlike conventional risk assessments that rely primarily on medical conditions, the proposed model identifies actionable risk factors that can be addressed through individualized interventions, such as digital health education, active family engagement, medication simplification, and pharmacist-led medication review (Liu et al., 2024; Arima et al., 2025; Poojar et al., 2024). The findings also reinforce the recommendations of Comprehensive Geriatric

Assessment, which emphasize that optimal transitional care requires evaluation of not only physical health but also cognitive, social, and medication-related factors (Setiati et al., 2024; Urquiza et al., 2025).

The findings of this study have important implications for geriatric care beyond the Indonesian context. As population ageing continues worldwide, preventing delayed follow-up after hospital discharge has become increasingly important for reducing avoidable complications, hospital readmissions, and healthcare costs. The proposed prediction model provides a simple framework for identifying high-risk older adults who may benefit from targeted transitional care interventions before discharge. Nevertheless, this study was conducted in a single hospital, which may limit the generalizability of the findings. Therefore, external validation in different healthcare settings and populations is recommended, together with the development of digital decision-support systems that can facilitate routine implementation of the prediction model in clinical practice (Lu et al., 2024; Setiati et al., 2024; Urquiza et al., 2025).

CONCLUSION

This study demonstrated that delayed post-discharge follow-up occurred in approximately one-third of geriatric patients and was independently predicted by low digital health literacy, poor family support, and high medication regimen complexity, with medication regimen complexity being the strongest predictor. The developed prediction model showed good discriminative performance (AUROC = 0.821), indicating its potential as a practical screening tool for identifying patients at high risk before hospital discharge. Early identification of high-risk patients may facilitate targeted interventions, including digital health education, family engagement, and medication optimization, to improve continuity of care and reduce adverse outcomes among older adults. Future studies should validate the model in broader populations and diverse healthcare settings to confirm its generalizability and support its implementation in routine geriatric care.

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