Research Square

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SEapp versus MIMIC score for predicting spontaneous ureteral stone passage

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Research Article

Keywords: stone passage, decision-support tool, large language models, urolithiasis, AI

Posted Date: April 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9233651/v1

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Additional Declarations: No competing interests reported.

Abstract

PURPOSE - A generative artificial intelligence–based clinical decision-support tool (Spontaneous Expulsion app; SEapp) was developed and prospectively validated to estimate spontaneous stone passage (SSP) in patients with ureteral lithiasis. The secondary objective was to compare its predictive performance with the MIMIC score.

METHODS - SEapp was developed using a standardized large language model (LLM)-based architecture powered by ChatGPT (OpenAI). A fixed structured prompt template incorporating predefined clinical, laboratory, and radiological variables was used to generate a probability estimate of SSP. In a second phase, a prospective, single-center, non-interventional cohort study was conducted to evaluate predictive performance. Discrimination was assessed using receiver operating characteristic (ROC) curves and area under the curve (AUC), and clinical utility was evaluated through decision curve analysis (DCA).

RESULTS - A consecutive series of 115 adult patients diagnosed with renal colic and radiologically confirmed ureteral lithiasis were prospectively enrolled. On univariable logistic regression analysis, stone location, stone density, maximum stone length, and neutrophil count were significantly associated with SSP (all $p < 0.01$). Sex, hydronephrosis, hydroureter, number of stones, and serum creatinine were not significantly associated with the outcome. SEapp demonstrated good discriminative performance with an AUC of 0.806 (95% CI 0.719–0.893), outperforming the MIMIC score (AUC 0.772; 95% CI 0.682–0.863) in the estimation of SSP. Decision curve analysis showed a consistently higher net clinical benefit for SEapp across clinically relevant probability thresholds (10–40%).

CONCLUSIONS - In this prospective cohort, SEapp demonstrated higher discriminative performance and clinical utility than the MIMIC score. External validation and controlled clinical integration are needed before widespread adoption.

Introduction

Urolithiasis is one of the most prevalent urological conditions and its initial clinical management remains challenging due to the difficulty in accurately predicting which patients will experience spontaneous stone passage (SSP) and which will require active intervention [1]. Clinical decision-making is typically based on a heterogeneous combination of anatomical, laboratory, and radiological parameters, whose individual prognostic value is not always clear and is rarely integrated into standardized, user-friendly predictive tools [1].

In recent years, artificial intelligence (AI) applications in urology have demonstrated significant potential in supporting and optimizing clinical decision-making processes: advanced large language models (LLMs), such as ChatGPT, have shown promising capabilities in processing complex clinical information and generating personalized decision-support outputs [2–6].

Based on these premises, the present study aimed to develop and prospectively validate a generative AI–based clinical decision-support tool, the Spontaneous Expulsion app (SEapp), designed to estimate the probability of SSP using predefined, readily available clinical variables.

The secondary objective was to assess the discriminative accuracy and clinical utility of this model by comparing its performance with the MIMIC score proposed by Shah et al [7, 8], in a consecutive cohort of patients with ureteral lithiasis.

Material & Methods

Study Design

The study was conducted in two sequential phases: (1) development of an AI–based clinical decision-support tool – the Spontaneous Expulsion app (SEapp), and (2) prospective clinical validation with comparison to the MIMIC score. The study was approved by the local ethics committee and conducted in accordance with the Declaration of Helsinki.

Phase 1: Development of the Spontaneous Expulsion app (SEapp)

SEapp was developed as a large language model (LLM)–based clinical decision-support tool powered by ChatGPT (OpenAI). Its primary objective was to estimate the probability of SSP in adult patients with ureteral stones by integrating predefined clinical, laboratory, and radiological parameters.

Model development was informed by previously published multivariate predictive models, incorporating established prognostic factors for SSP, including stone size, ureteral location (proximal, mid, distal), neutrophil-to-lymphocyte ratio (NLR), degree of hydronephrosis, stone density measured in Hounsfield Units (HU), and urinary inflammatory markers[9–15]. Additional evidence from recent studies on ureteral wall thickness (UWT) and AI-based predictive systems was also integrated [11, 16].

These variables were incorporated into a fixed structured and semi-structured prompt template (e.g., “8-mm distal ureteral stone, 600 HU, moderate hydronephrosis, NLR 3.5”). For each case, predefined variables were entered into SEapp using the standardized template and the model generated a probabilistic estimate (0–100%) of SSP. The interface was intentionally designed for educational and decision-support purposes only, avoiding therapeutic recommendations and consistently encouraging specialist urological evaluation.

SEapp works as a clinical decision support system (CDSS) rather than a diagnostic device. Probability estimates are derived from probabilistic extrapolation of published evidence rather than supervised machine-learning training on proprietary clinical datasets. The model is accessible online at the following link: https://urology.moretti.cc/.

Phase 2: Prospective Validation and Comparison with the MIMIC Score

A prospective, single-center, non-interventional cohort study was conducted. Consecutive adult patients presenting to the emergency department with renal colic and radiologically confirmed ureteral lithiasis were enrolled between December 2024 and November 2025.

Eligibility Criteria

Inclusion criteria:

- Age ≥ 18 years
- Ureteral stone confirmed by non-contrast computed tomography (NCCT)
- Availability for a 30-day follow-up

Exclusion criteria:

- Active urinary tract infection
- Fever or signs of sepsis
- Renal impairment requiring urgent drainage
- Recent urological intervention (< 6 months)

Patient Management

All patients received medical expulsive therapy (MET) with an alpha-blocker (tamsulosin), in accordance with current international guidelines [17–19]. Nonsteroidal anti-inflammatory drugs (NSAIDs) were administered for pain control as clinically indicated. SEapp predictions were generated independently and did not guide treatment decisions.

Variables

The variables collected and processed by SEapp were: number of stones, maximum stone length, ureteral stone location, stone density (HU), presence of hydronephrosis and hydroureter, serum creatinine levels, neutrophil count.

MIMIC Score Calculation

The MIMIC score, developed by the BURST Urology collaborative, was calculated for each patient using sex, neutrophil count, hydronephrosis, hydroureter, MET use, stone size, stone location, and NSAID administration to estimate SSP probability [7].

Statistical Analysis

Continuous variables were reported as mean ± standard deviation or median (IQR), as appropriate. Group comparisons were performed using Student's t-test or Mann–Whitney U test for continuous variables and χ^2 or Fisher's exact test for categorical variables. Univariable logistic regression was performed to evaluate the association between predefined clinical variables and SSP. SEapp and MIMIC scores were evaluated separately as predictive tools. Discrimination was assessed using receiver operating characteristic (ROC) curves and the area under the curve (AUC). Clinical utility was evaluated through decision curve analysis (DCA), comparing net benefit across probability thresholds against "treat-all" and "treat-none" strategies. Statistical analyses were performed using SPSS version 27 (IBM Corp., Armonk, NY, USA). A two-sided p-value < 0.05 was considered statistically significant. No missing data were observed for variables included in the analysis.

Results

A consecutive series of 115 patients were enrolled, including 69 men (60%) and 46 women (40%). Patient's characteristics are enlisted in Table 1. All patients received medical expulsive therapy with an alpha-blocker at diagnosis. Hydronephrosis was documented in 77/115 patients (67%). Regarding stone burden, 100 patients (87%) had a single stone, 5 (4.3%) had two stones, 9 (7.8%) had three stones, and 1 (0.9%) had four stones. Stone location was juxtavesical in 20 patients (17.4%), distal ureter in 45 (39.1%), mid ureter in 21 (18.3%), and proximal ureter in 29 (25.2%). Spontaneous stone passage (SSP) occurred in 38 patients (33%) within 30 days. The morphological and laboratory characteristics of stones and patients are summarized as follows: the median stone density was 761 (500–1000) HU, while the maximum length had a median of 6 (5–8) mm. Median creatinine serum was 1 (0.8–1.1) mg/dL; median neutrophil count was 6.7 (4.4–9.5) $x10^3$ µL. Median SEapp score was 35 (20–50) %, and median MIMIC score was 63 (43–72) %. Baseline characteristics stratified by SSP are presented in Table 2. Patients who achieved SSP had significantly smaller stones, lower stone density, and higher neutrophil counts compared with those who did not. No significant differences were observed in sex, hydronephrosis, hydroureter, number of stones, or serum creatinine levels.

On univariable logistic regression analysis, stone location, stone density, maximum stone length, neutrophil, SEapp probability, and MIMIC score count were significantly associated with SSP (all p < 0.01) (Table 3).

Specifically:

- Stone location (OR 0.503; 95% CI 0.328–0.769; p < 0.001): probability of expulsion decreased with increasing distance from the ureterovesical junction.
- Stone density (OR 0.996; 95% CI 0.994–0.997; p < 0.001): higher HU values were associated with lower probability of SSP.

- Stone length (OR 0.602; 95% CI 0.471–0.767; p < 0.001): increasing size was associated with reduced likelihood of expulsion.
- SEapp score (OR = 1.071; 95% CI: 1.041–1.102; p < 0.001): an increase in SEapp score is positively associated with expulsion.
- MIMIC score (OR = 1.058; 95% CI: 1.032–1.085; p < 0.001): an increase in MIMIC score is associated with favourable outcome.
- Neutrophil count (OR 1.153; 95% CI 1.007–1.320; p = 0.009). Increased neutrophil counts were associated with a greater likelihood of expulsion.

Sex, hydronephrosis, hydroureter, number of stones, and serum creatinine were not significantly associated with SSP (Table 3).

SEapp demonstrated good discriminative ability, with an AUC of 0.806 (95% CI 0.719–0.893). The MIMIC score showed an AUC of 0.772 (95% CI 0.682–0.863) (Fig. 1).

Decision curve analysis demonstrated consistently higher net clinical benefit for SEapp compared with the MIMIC score across clinically relevant probability thresholds (10–40%) (Fig. 2, Fig. 3).

Discussion

The present study represents one of the first prospective clinical evaluations of a generative AI–based clinical decision-support tool for predicting spontaneous stone passage (SSP) in ureteral lithiasis. SEapp was designed to generate individualized probability estimates by integrating routinely available clinical, laboratory, and radiological variables. Unlike traditional static predictive scores, such as the MIMIC score [7], SEapp operates within a flexible LLM framework capable of synthesizing structured inputs into a continuous probability output, through an intuitive conversational interface, potentially improving clinical usability and applicability in real-world settings.

In this prospective cohort, SEapp demonstrated good discriminative ability (AUC 0.806) and superior clinical utility compared with the MIMIC score. Decision curve analysis showed consistently greater net benefit across clinically relevant probability thresholds, particularly between 10% and 40%. This range represents a critical decision zone in routine practice, where clinicians must balance continued conservative management against early intervention. These findings suggest that SEapp may support risk stratification, particularly in scenarios characterized by therapeutic uncertainty. A recent external validation of the MIMIC score was conducted by Milton et al at the Royal Adelaide Hospital in Australia [20]. This retrospective study included 399 patients with acute ureteral colic managed conservatively over two years [20]. Results showed that the area under the receiver operating characteristic curve (AUC) of the MIMIC score was 0.68 (95% CI: 0.60–0.77), indicating moderate discriminatory ability [20]. The model tended to underestimate the probability of spontaneous expulsion in low-risk patients: in the quintile with a mean predicted probability of 46%, the observed rate of SSP was 74% (95% CI: 63–83%) [20]. However, in the quintile with the highest predicted probability (mean 90%), the observed rate of SSP

was 92% (95% CI: 84–97%), suggesting good predictive accuracy in high-risk patients [20]. One of the major strengths of this study lies in its prospective design and homogeneous patient management. The cohort included 115 consecutive patients with symptomatic ureteral stones, all treated with standardized medical expulsive therapy and systematically evaluated with radiological follow-up at 30 days. This approach enhances the internal validity of the findings and reflects real-world clinical practice. In addition, the integration and comparison with a validated predictive model such as the MIMIC score [7, 20] allowed an objective evaluation of SEapp performance under clinically relevant conditions. The higher AUC observed for SEapp supports its strong discriminatory capacity and highlights the potential advantages of AI-driven predictive systems in complex clinical scenarios. Regarding individual predictors, our findings are consistent with existing literature, suggesting that the characteristics of the study cohort are aligned with previously reported clinical patterns of spontaneous stone passage. Stone location was significantly associated with spontaneous expulsion, with distal ureteral stones demonstrating significantly higher success rates compared to mid or proximal stones [9]. This observation reinforces previous evidence and confirms the importance of anatomical assessment in the initial evaluation of renal colic. Stone size was likewise confirmed as a key determinant of conservative management success. Increasing stone length was associated with a substantial increase in the risk of expulsion failure, supporting the need for accurate measurement of maximum stone diameter on computed tomography and its integration into decision-making processes [10].

Stone density, expressed as Hounsfield units, further contributed to outcome prediction. In line with previous studies, higher HU values were inversely associated with spontaneous expulsion, reflecting the reduced friability and mobility of denser stones [11]. The association between HU and SSP supports the relevance of quantitative radiological parameters within predictive tools such as SEapp, beyond stone size and location alone.

An additional and clinically relevant finding of the present study is the role of systemic inflammation. The role of absolute neutrophilia in predicting SSP remains controversial. Some studies have reported an increased likelihood of SSP in patients with elevated neutrophil counts, whereas others have found higher passage rates in patients with normal neutrophil levels [12, 13, 15]. In our cohort, higher neutrophil counts were associated with an increased likelihood of expulsion. This finding is consistent with the original MIMIC study, in which neutrophil count was positively associated with SSP in univariable analysis [7]. The heterogeneity of these findings may reflect differences in patient selection, timing of laboratory assessment, and the complex, potentially bidirectional role of inflammation. On one hand, a migrating stone may induce ureteral wall inflammation and trigger a systemic inflammatory response, resulting in elevated neutrophil counts. On the other hand, a sustained inflammatory response may reflect persistent ureteral irritation, edema, spasm, and obstruction, potentially hindering stone passage. Although inflammatory markers are not specific to stone disease, their integration into predictive models may provide incremental prognostic information and deserve further investigation in larger, multicenter cohorts.

The spontaneous expulsion rate observed in this study was lower than that reported in large multicenter series [7]. This difference can be explained by the specific clinical characteristics of our cohort, which included a higher proportion of patients with larger stones and mid-to-proximal ureteral location. While this supports the robustness of the model in a more challenging population, it also represents an important limitation. The predictive performance of SEapp may not be directly generalizable to populations with different baseline characteristics, and external validation in broader and more heterogeneous cohorts is therefore required.

The introduction of generative AI into predictive medicine represents a promising but still evolving frontier. Large language models such as ChatGPT offer the ability to synthesize complex and potentially nonlinear clinical data and to present predictions through an accessible and intuitive interface [4, 21]. In our study, these capabilities enabled rapid and personalized estimation of expulsion probability, with potential applications in both emergency and outpatient settings. However, several limitations inherent to this technology must be acknowledged.

First, SEapp does not account for dynamic clinical variables such as symptom progression, response to therapy, patient comorbidities, or clinician expertise, which remain central to individualized medical decision-making. Second, variability in AI-generated outputs and dependence on underlying training data raise concerns regarding reproducibility and standardization, which are essential prerequisites for clinical implementation [22]. Third, imperfect adherence to clinical guidelines in complex scenarios has been reported, emphasizing the need for supervised, continuously updated, and clinically controlled AI systems [23, 24].

Despite these limitations, AI-based tools should be regarded as decision-support systems rather than replacements for clinical judgment. Their primary value lies in improving risk stratification, supporting consistency in decision-making, and assisting physicians in managing complex clinical scenarios involving multiple interacting variables. From this perspective, SEapp represents a proof-of-concept for the responsible integration of generative AI into urological practice. Future developments should focus on external multicenter validation, integration with dynamically updated clinical data, and close collaboration between clinicians and data scientists.

Conclusions

In this prospective cohort, SEapp demonstrated good discriminative performance and higher clinical utility than the MIMIC score in predicting spontaneous ureteral stone passage. Established predictors such as stone location, size, and density were confirmed, while neutrophil count emerged as an additional associated factor. Generative AI–based tools may support risk stratification when used as clinical decision-support systems rather than replacements for physician judgment. External validation and calibration assessment are required before routine clinical implementation.

Declarations

Competing interests

The authors declare no competing interests.

Funding

No funding was received to assist with the preparation of this manuscript.

Author Contribution

Conceptualization: R:L., A.N.; Methodology: A.C, A.M.; Formal analysis and investigation: R.L, A.F; Writing - original draft preparation: M.S., E.P., M.N.; Writing - review and editing: A.C., G.T, B.T; Supervision: C.D.N., A.T.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available due to institutional and privacy restrictions but are available from the corresponding author on reasonable request.

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Tables

Table 1
Patient's characteristics

Variables	Results n (%), median [IQR]
Sex (M/F)	69/46
MET[1]	115/115 (100%)
Hydronephrosis	77/115 (88,5%)
Stones number	
1	110/115 (87%)
2	5/115 (4,3%)
3	9/115 (7,8%)
4	1/115 (0,9%)
Stone location	
juxtavesical	20/115 (17,4%)
distal	45/115 (39,1%)
mid	21/115 (18,3)
proximal	29/115 (25,2%)
SSP[2]	38/115 (33%)
Stone density (HU)	761 [500–1000]
Maximum length (mm)	6 [5–8]
Creatinine (mg/dL)	1 [0,8 – 1,1]
Neutrophils (×10³/µL)	6,7 [4, 4–9, 5]
SEapp[3] score (%)	35 [20–50]
MIMIC score (%)	63 [43–72]

[1]MET: Medical Expulsive Therapy; [2]SSP: Spontaneous Stone Passage; [3]SEapp: Spontaneous Expulsion app.

Table 2
Comparison between patients with or without spontaneous stone expulsion

Variable	No SSP (n = 77)	Yes SSP (n = 38)	p
Sex			
M (69)	47 (61%)	22 (58%)	0.746
F (46)	30 (39%)	16 (42%)	
MET[1]	77 (100%)	38 (100%)	1.000
Hydronephrosis			
Yes	52 (68)	25 (66)	0.639
No	25 (32%)	13 (34)	
Hydroureter			0.188
Yes	36 (47%)	19 (50%)	
No	41 (53%)	19 (50%)	
Number of stones			0.535
1	68 (88%)	32 (84%)	
2	2 (3%)	3 (8%)	
3	6 (8%)	3 (8%)	
4	1 (1%)	0	
Stone location			< 0.001
Juxtavesical	3 (4%)	17 (45%)	
Distal	39 (50%)	6 (16%)	
Mid	10 (13%)	11 (29%)	
Proximal	25 (33%)	4 (10%)	
Stone density (HU)	900 [700–1101]	500 [400–703]	< 0.001
Maximum length (mm)	7 [6–10]	5 [3–6]	< 0.001
Creatinine (mg/dL)	1.0 [0.89–1.17]	1.0 [0.77–1.18]	0.471
Neutrophils (×10³/µL)	5.8 [4.1–8.7]	8.2 [6.8–10.4]	0.009
SEapp[2] score (%)	30 [20–40]	52.5 [39–61]	< 0.001

[1]MET: Medical Expulsive Therapy; [2]SEapp: Spontaneous Expulsion app

Variable	No SSP (n = 77)	Yes SSP (n = 38)	p
Sex			
MIMIC score (%)	52 [38–69]	72 [55–90]	< 0.001
[1]MET: Medical Expulsive Therapy; [2]SEapp: Spontaneous Expulsion app			

Table 3
Univariable Logistic Regression

Variable	OR (95% CI)	p
Sex	0.878 (0.398–1.934)	0.746
Hydronephrosis	1.059 (0.573–1.956)	0.639
Hydroureter	2.243 (0.66–7.61)	0.188
Number of stones	1.042 (0.56–1.93)	0.535
Stone location	0.503 (0.328–0.769)	0.001
Stone density	0.996 (0.994–0.997)	0.001
Maximum length	0.602 (0.471–0.767)	0.001
Creatinine	0.773 (0.201–2.969)	0.471
Neutrophils	1.153 (1.007–1.320)	0.009
SEapp[1] score	1.071 (1.041–1.102)	0.001
MIMIC score	1.058 (1.032–1.085)	0.001
[1]SEapp: Spontaneous Expulsion app		

Figures

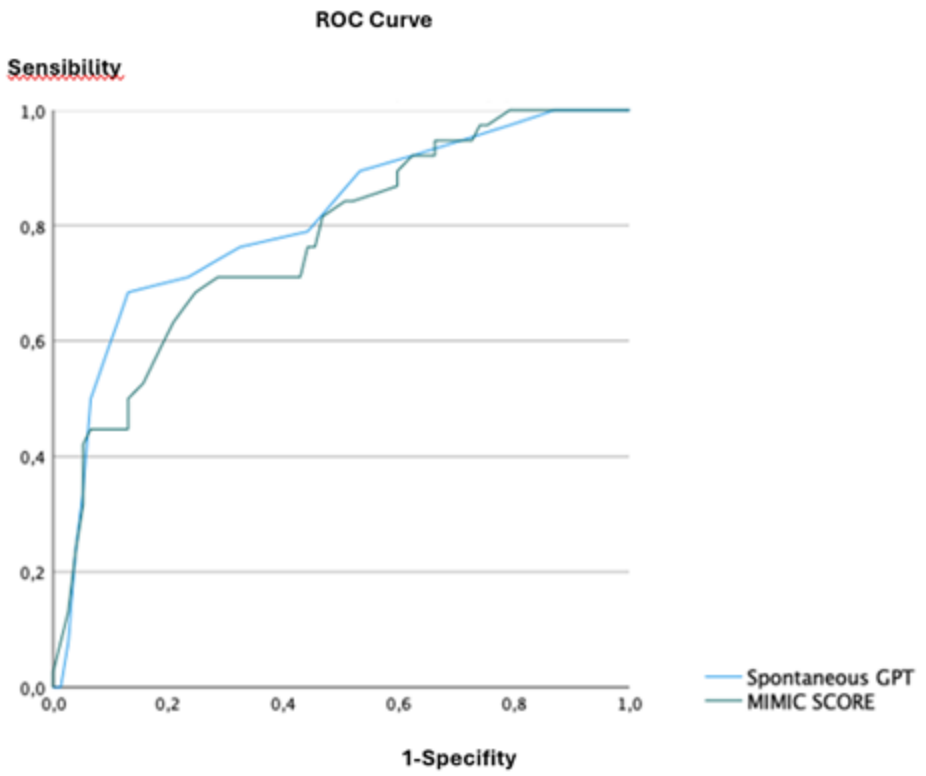


Figure 1

SEapp e MIMIC score ROC Curves

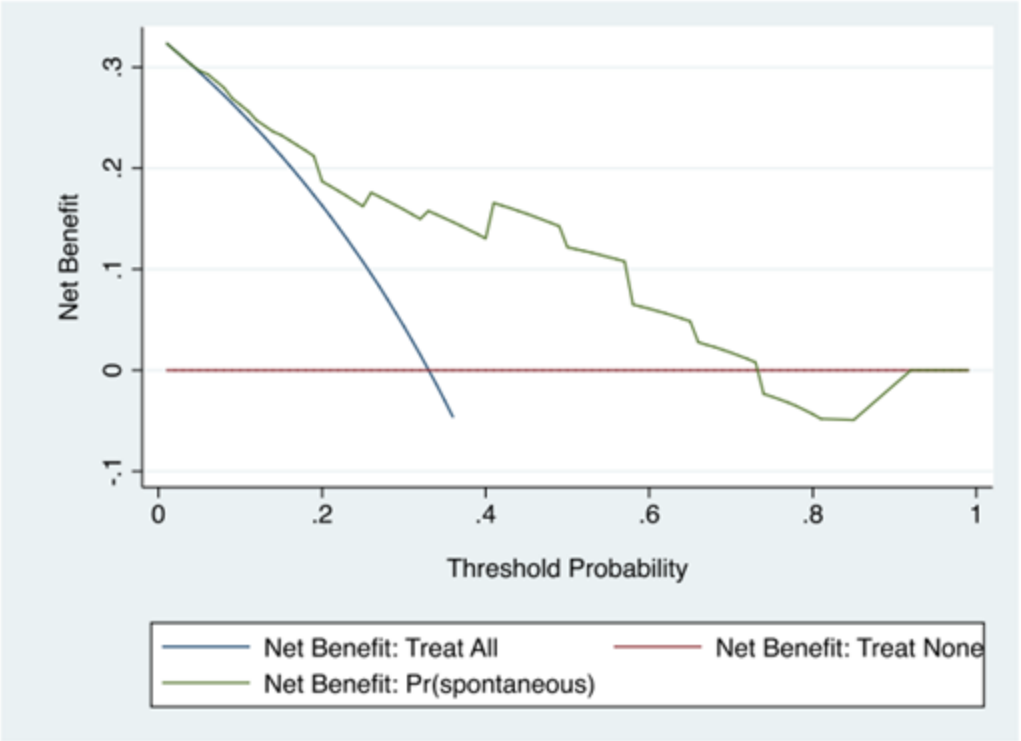


Figure 2

Decision curve analysis for SEapp

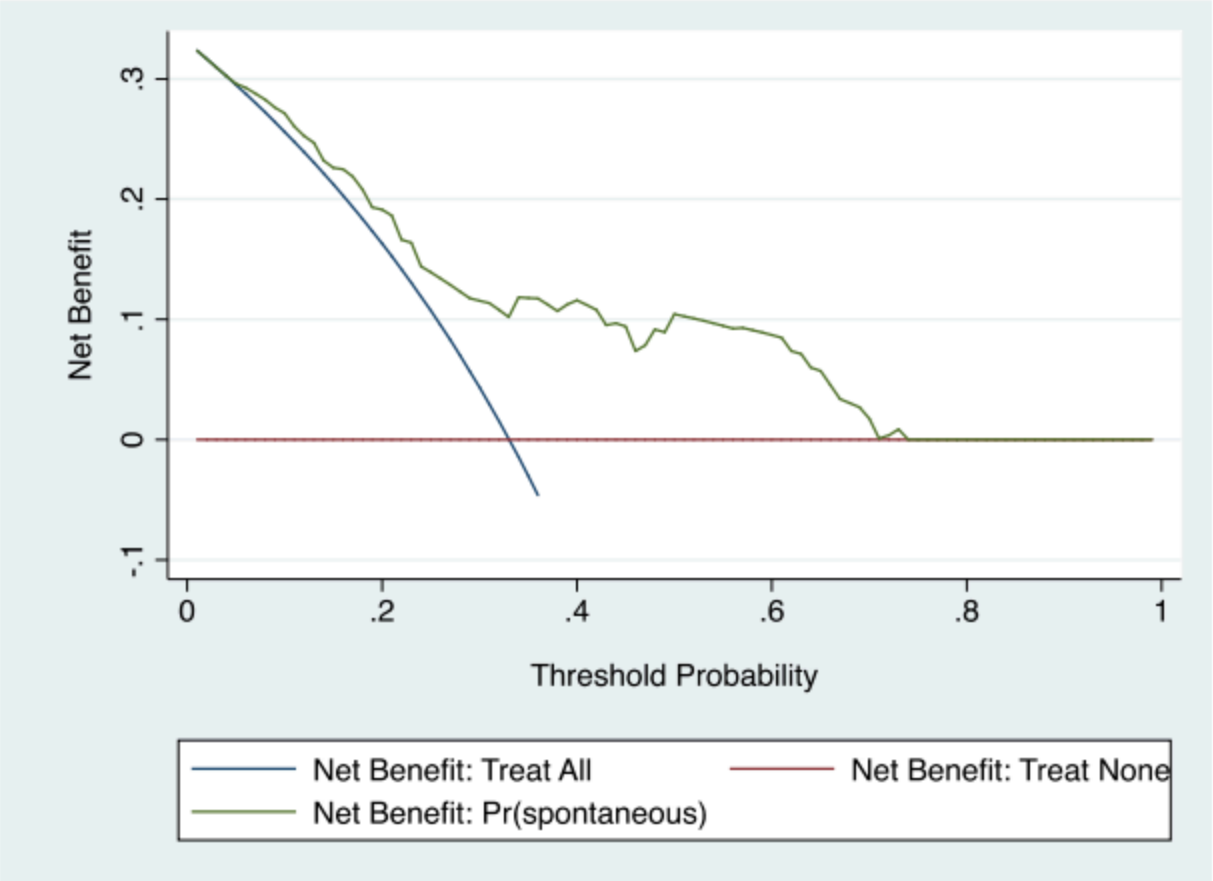


Figure 3

Decision curve analysis for MIMIC score