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REPORTS OF ORIGINAL INVESTIGATIONS

Clinical prediction model to identify vulnerable patients in ambulatory surgery: towards optimal medical decision-making

Un modèle de prédiction clinique permettant d'identifier les patients en chirurgie ambulatoire vulnérables: vers une prise de décision médicale optimale

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Abstract

Background *Ambulatory surgery patients are at risk of adverse psychological outcomes such as anxiety, aggression, fatigue, and depression. We developed and validated a clinical prediction model to identify patients who were vulnerable to these psychological outcome parameters.*

Methods *We prospectively assessed 383 mixed ambulatory surgery patients for psychological vulnerability, defined as the presence of anxiety (state/trait), aggression (state/trait), fatigue, and depression seven days after surgery. Three psychological vulnerability categories were considered–i.e., none, one, or multiple poor scores, defined as a score exceeding one standard deviation above the mean for each single outcome according to normative data. The following determinants were assessed preoperatively: sociodemographic (age, sex, level of education, employment status, marital status, having children, religion, nationality), medical (heart rate and body mass index), and psychological variables (self-esteem and self-efficacy), in addition to anxiety, aggression, fatigue, and depression. A prediction model was constructed using ordinal polytomous logistic regression analysis, and bootstrapping was applied for internal validation. The ordinal c-index (ORC) quantified the discriminative ability of the model, in addition to measures for overall model performance (Nagelkerke's* R^2*).*

Results *In this population, 137 (36%) patients were identified as being psychologically vulnerable after surgery for at least one of the psychological outcomes. The most parsimonious and optimal prediction model combined sociodemographic variables (level of education, having children, and nationality) with psychological variables (trait anxiety, state/trait aggression, fatigue, and depression). Model performance was promising:* $R^2 = 30\%$ *and ORC = 0.76 after correction for optimism.*

Conclusion *This study identified a substantial group of vulnerable patients in ambulatory surgery. The proposed clinical prediction model could allow healthcare professionals the opportunity to identify vulnerable patients in ambulatory surgery, although additional modification and validation are needed. (ClinicalTrials.gov number, NCT01441843).*

Résumé

Contexte *Les patients de chirurgie ambulatoire courent un risque de complications psychologiques telles que l'anxiété, l'agressivité, la fatigue et la dépression. Nous avons mis au point et validé un modèle de prédiction clinique permettant d'identifier les patients vulnérables à ces paramètres de complications psychologiques.*

Méthode *Nous avons évalué la vulnérabilité psychologique de 383 patients de chirurgie ambulatoire des deux sexes de façon prospective. La vulnérabilité psychologique a été définie comme la présence d'anxiété (état/trait), d'agressivité (état/trait), de fatigue et de dépression sept jours après la chirurgie. Trois catégories*

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de vulnérabilité psychologique ont été prises en compte, c'est-à-dire aucun, un ou plusieurs scores bas. Un score bas était défini en tant que score excédant un écart type au-dessus de la moyenne pour chacune des variables spécifiques selon les données normatives. Les déterminants suivants ont été évalués en période préopératoire : les variables sociodémographiques (âge, sexe, degré d'instruction, situation d'emploi, état matrimonial, présence d'enfants, religion, nationalité), les variables médicales (fréquence cardiaque et indice de masse corporel) et les variables psychologiques (estime de soi et connaissance de ses propres capacités), ainsi que l'anxiété, l'agressivité, la fatigue et la dépression. Un modèle de prédiction a été élaboré en se servant d'une analyse de régression logistique polytomique ordinale, et une méthode de ré-échantillonnage de type Bootstrap a été appliquée pour la validation interne. L'indice c ordinal (ORC) quantifiait la capacité discriminatoire du modèle, outre les mesures de la performance globale du modèle (le R^2 de Nagelkerke).

Résultats *Dans cette population, 137 (36 %) patients ont été identifiés comme étant psychologiquement vulnérables après la chirurgie en ce qui touchait à au moins un des critères psychologiques. Le modèle de prédiction le plus parcimonieux et optimal combinait des variables sociodémographiques (degré d'instruction, présence d'enfants et nationalité) à nos variables psychologiques (trait d'anxiété, état/trait d'agressivité, fatigue et dépression). La performance du modèle était prometteuse : R^2 = 30 % et ORC = 0,76 après correction pour tenir compte de l'optimisme.*

Conclusion *Cette étude a identifié un groupe considérable de patients vulnérables en chirurgie ambulatoire. Le modèle de prédiction clinique proposée pourrait donner aux professionnels de la santé l'occasion d'identifier les patients vulnérables en chirurgie ambulatoire, bien que des modifications et une validation supplémentaires soient nécessaires. (Numéro ClinicalTrials.gov, NCT01441843).*

Ambulatory surgery is increasing in the Western world in parallel with improved surgical safety due to advancements in anesthesia and surgical techniques. Perioperative morbidity and mortality in adult ambulatory surgery is less than 0.1%.[1] Quality of life, along with endpoints like pain and transient loss of function, has become a more important clinical endpoint in ambulatory surgery, which is dominated by psychological outcome parameters such as anxiety, aggression, fatigue, and depression.[2] Over the last decades, prediction research has been performed on somatic outcomes in ambulatory surgery patients,[1,3-5] but prediction models tailored to psychological outcomes are lacking. Nevertheless, poor psychological outcomes in patients can have negative socioeconomic consequences due to prolonged convalescence that delays a return to normal activities and work.[6-10]

Accordingly, it is of clinical interest to predict which patients are at risk of psychological vulnerability after ambulatory surgery. Patients are considered vulnerable if they deviate substantially from the norm in terms of their psychological outcome parameters. If psychological vulnerability can be predicted before surgery, appropriate action could be taken as needed to improve outcomes after ambulatory surgery.

The objective of this study was to create and test a model that identifies psychologically vulnerable ambulatory surgery patients. Towards this end, we constructed and validated a clinical prediction model that included sociodemographic, medical, and psychological determinants.

Methods

The study protocol was approved by the Medical Ethics Committee of Erasmus University Medical Center and by the Netherlands Central Committee on Research Involving Human Subjects. It was registered with EudraCT (#2010-020332-19). Written informed consent was obtained from all subjects.

Study population

This study comprises data from a larger randomized clinical trial published previously,[2] and parts of this Methods section were adapted to address the different objectives of the current study.

Briefly, 400 patients were recruited from our ambulatory surgery department during October 2010 to September 2011. Inclusion criteria were patients who were at least 18 yr of age and referred for ambulatory surgery. Exclusion criteria were patients who clearly had an insufficient command of the Dutch language or an intellectual disability, patients undergoing procedures generally considered less invasive (i.e., ophthalmology surgery, extracorporeal shock wave lithotripsy, endoscopy, Botox treatment, abortion, or chronic pain), those who previously used psychopharmaceuticals, and those with contraindications to the use of lorazepam. Patients were randomized to either the lorazepam group or the placebo (NaCl 0.9%) group in the original randomized-controlled trial (RCT). Healthcare professionals, patients, and researchers were all blinded to the medication given.

Procedure and intervention

All patients scheduled for ambulatory surgery received written information about the trial at least one week before surgery. A member of the research group enrolled patients after their admission to the ambulatory surgery centre and sought written informed consent. Patients who consented to participate completed a set of online questionnaires while waiting for surgery (T0). The study medication was then administered in the preoperative holding period. On the sixth day after surgery, one of the researchers telephoned the patients to remind them to complete the last set of online questionnaires the next day (T1).

Outcome variables

Anxiety was measured using the Dutch version of the State-Trait Anxiety Inventory (STAI).[11] The STAI consists of two 20-item scales. One scale measures how people generally assess their feelings, i.e., trait anxiety (STAI-T), and the other scale measures how people assess their feelings at the present moment, i.e., state anxiety (STAI-S). Sum scores for both scales are calculated by summing the scores for the items. The theoretical range is from 20-80, with a higher score indicating a higher level of anxiety. The STAI has good validity, and the STAI-S and STAI-T scales have overall similar reliability scores, with Cronbach's $\alpha >$ 0.80.[11]

Aggression regulation was assessed using the Dutch translated version of the State-Trait Anger Scale (STAS),[12] which consists of two ten-item scales. One scale measures state aggression, i.e., how people assess their anger intensity at the moment (STAS-S), and the other scale measures trait aggression, i.e., how people generally assess their anger intensity (STAS-T). Sum scores for both scales are calculated by summing the scores for the items. The theoretical range is from 10-40, with a higher score indicating a higher level of aggression. Both subscales have adequate validity, and both the STAS-S and the STAS-T have good reliability scores, with Cronbach's α values of 0.93 and 0.88, respectively.[12]

Fatigue was measured using the Dutch version of the Multidimensional Fatigue Inventory (MFI),[13] a 20-item questionnaire that comprises five four-item scales: general fatigue, physical fatigue, mental fatigue, reduced motivation, and reduced activity. Sum scores are calculated by summing the scores for the items. The theoretical range is from 20-100, with a higher score indicating a higher degree of fatigue. In the majority of cases, the MFI has good validity and reliability, with Cronbach's α exceeding 0.80.[13]

Depressive moods were measured using a Dutch translated version of the Hospital Anxiety and Depression Scale (HADS),[14] which consists of two seven-item scales. One scale measures anxiety (HADS-A), and the other scale measures depression (HADS-D). Sum scores for both scales are calculated by summing the scores on the items. The theoretical range is from 0-21, with a higher score indicating moods that are more depressive. The HADS has adequate validity and internal consistency in the Dutch population (Cronbach's α = 0.88).[15]

All outcomes were assessed at T1 (postoperative day 7).

Determinants

The sociodemographic candidate determinants were sex, age, educational level, marital status, employment, religion, having children, and type of nationality. The medical candidate determinants were body mass index (BMI) and preoperative heart rate. Psychological candidate determinants included all baseline assessments of the psychological outcome variables, self-esteem, and self-efficacy.

Self-esteem was measured using the Dutch version of the Rosenberg Self-Esteem Scale (RSES).[16] Sum scores are calculated by summing the scores on the items. The theoretical range is from 10-40, with a higher score indicating a higher degree of self-esteem. The RSES has good validity and reliability (Cronbach's α = 0.87).[16]

Self-efficacy was measured using the Dutch version of the General Self-Efficacy Scale (GSES).[17] Sum scores are calculated by summing the scores for the items. The theoretical range is from 10-40, with a higher score indicating a higher degree of self-esteem. The GSES has adequate validity and good reliability (Cronbach's α = 0.85) in the Dutch population.[18]

All determinants were assessed at T0 (preoperatively).

Definition of vulnerability

According to recent research in our field, use of constructed composite scales according to normative data is a practical way to screen for postoperative psychological outcomes.[19] We used the 84th percentile cut-off as, to date, this is normally applied in clinical prediction studies to identify aberrant patients.[20-22] Thus, likewise, patients in the present study were considered vulnerable after surgery if they scored a standard deviation (SD) of $\geq$ 1 above the mean in the normal population on the outcome variables. The mean (SD) norm scores were as follows: STAI-S, 34.8 (8.4); STAI-T, 36.9 (8.4); MFI, 41.1 (16.1); STAS-S, 11.2 (3.1); STAS-T, 16.7 (4.0); HADS-A, 5.1 (3.6); and HADS-D, 3.4 (3.3).[11,12,23,24] The literature does not report norm scores for STAI and STAS, so these were obtained from the Dutch manual using the students' category as the most appropriate reference group. Vulnerability was

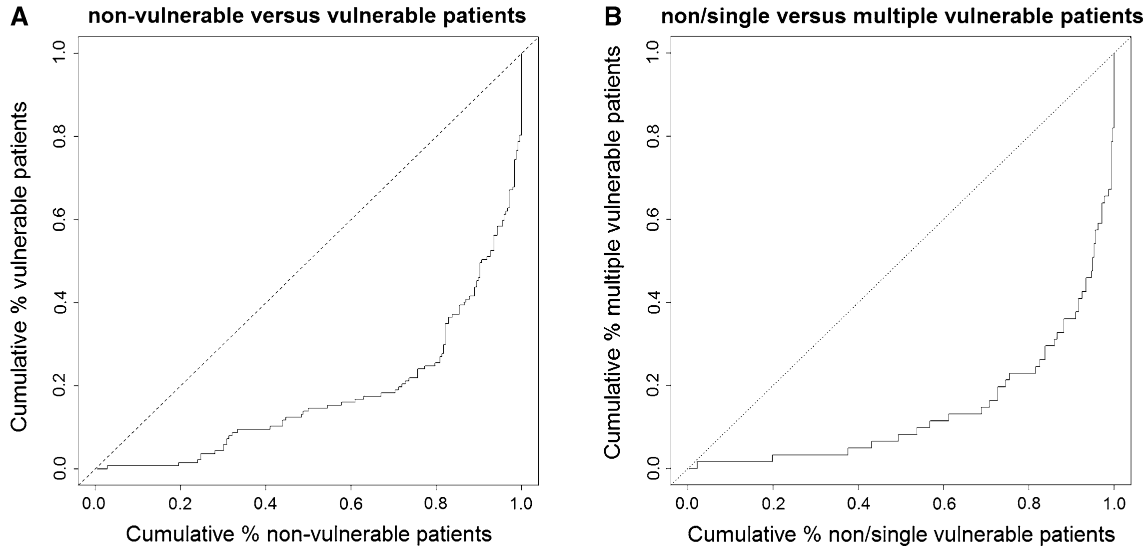

Figure Lorenz curves for 383 patients enrolled in a randomized-controlled trial. The graphs show the relation between the cumulative proportion of patients who are classified as non-vulnerable while they are vulnerable (y-axis, Figure A) *vs* classified as non-vulnerable among the non-vulnerable patients. Figure B) classification as non-vulnerable or as scoring only one vulnerable outcome *vs* multiple vulnerability.

subsequently calculated on how many of the seven outcome parameters a patient scored in the vulnerability region. Consequently, vulnerability scores could range from 0 (not at all vulnerable) to 7 (vulnerable for all seven outcome variables). Patients were categorized as non-vulnerable (V_0, vulnerability score 0), single vulnerable (V_1, vulnerability score 1), and multiple vulnerable (V_2, vulnerability score $\geq$ 2).

Statistical analysis

Of the 400 patients enrolled in the original RCT, data from 398 patients were eligible for analysis.[2] Of these, 383 patients completed the measurements on the seventh day after surgery. We calculated percentages and means as measures of a central tendency for determinants and outcome variables in these 383 patients. For continuous data, the standard deviation was presented as a measure of dispersion. Analyses were adjusted for the intervention and randomized together with the type of surgical specialty and the type of anesthesia.

Modelling strategy and validation

Ordered polytomous logistic regression analysis was used to develop the prediction model. All determinants were included in the model followed by a backward elimination procedure (p-to-remove > 0.20). Akaike's Information Criterion was evaluated during the modelling procedure. The final model was subjected to bootstrapping (1,000 times) for internal validation.[25] The discriminative ability of the resulting prediction model was measured using the ordinal *c*-index (ORC).[26] The ORC can be interpreted as the probability to rank cases correctly from two randomly selected categories. If a model orders patients randomly, the ORC is equal to 0.5; with perfect ordering, the ORC is equal to 1. Lorenz curves were constructed to visualize discrimination between the vulnerability categories.[27] The Lorenz curve can well be used in clinical research to indicate discrimination between diseased and non-diseased states.[28]

Overall model performance was measured using Nagelkerke's R^2.[29] All performance measures were corrected for optimism by bootstrapping (i.e., internal validation).[25] We used SPSS® version 20.0 (IBM Corp., Armonk, NY, USA) for statistical analyses. Performance measures were calculated in R version 3.0.1.[30] Results were considered statistically significant if the two-sided *P* was < 0.05.

Results

Patients

We found that 137 (36%) of the 383 ambulatory surgery patients were psychologically vulnerable, with 76 patients being single-domain vulnerable and 61 patients being multiple-domain vulnerable after surgery (Table 1). In the non-vulnerable group, 61% (n = 150) were male, whereas in both the single and multiple vulnerable groups, 50% were male. In all vulnerability categories, the majority of the patients had a middle-level education. Most patients

Table 1 Vulnerability categories

Vulnerable points	*n*	%
None	246	64.2
One	76	19.8
Two	27	7.0
Three	10	2.6
Four	13	3.4
Five	5	1.3
Six	4	1.0
Seven	2	0.5

White = non-vulnerable patients (V_0); light gray = single vulnerable patients (V_1); dark gray = multiple vulnerable patients (V_2)

were employed, and more than half of the patients lived with a partner. Patients of Dutch nationality dominated the study population (Table 2).

The mean range of values for age (38.4-40.0) yr, BMI (25.1-25.8) kg·m^{-2}, and preoperative heart rate (70-72) beats·min^{-1} were nearly equally distributed in the three vulnerability categories. As expected, preoperative anxiety, aggression, fatigue, and depression scores were lowest in the non-vulnerable group and highest in the multiple vulnerable group. Similarly, the self-esteem and self-efficacy scores were worse in the multiple vulnerable group (Table 2).

Univariate and multivariable analyses

Table 3 presents the univariate and multivariable odds ratios (ORs) of the candidate determinants in the clinical prediction model. We focused on the ORs of the determinants in the multivariable prediction model. The level of education was an important predictor for vulnerability (OR for a middle-level education, 1.73; 95% confidence interval [CI], 0.88 to 4.24; OR for a high-level education, 1.92; 95% CI, 0.74 to 6.18). Other

Table 2 Descriptions of baseline determinants distinguished by vulnerability category

Baseline determinants	Vulnerability categories					
	None (*n*=246)		Single (*n*=76)		Multiple (*n*=61)	
Categorical variables	*n*	%	*n*	%	*n*	%
Sex (male)	150	61.0	38	50.0	31	50.8
Education						
Middle	162	65.9	54	71.1	43	70.5
High	47	19.1	11	14.5	5	8.2
Employment (having)	193	78.5	57	75.0	39	63.9
Marital Status (together)	158	64.2	43	56.6	34	55.7
Children (yes)	124	50.4	35	46.1	40	65.6
Religion (yes)	74	30.1	24	31.6	26	42.6
Nationality (Dutch)	233	94.7	69	90.8	57	93.4
Continuous variables	Mean	SD	Mean	SD	Mean	SD
Age	40.0	14.3	38.4	12.8	39.8	12.3
BMI	25.1	4.2	25.4	4.1	25.8	4.0
Heart rate	70	13	72	13	71	13
STAI-S (20-80)*	35.7	8.8	40.7	9.6	43.3	8.9
STAI-T (20-80)*	30.9	6.2	35.4	7.7	41.8	9.2
STAS-S (10-40)*	10.1	0.7	10.3	1.4	10.5	2.2
STAS-T (10-40)*	12.7	2.9	14.0	3.7	15.6	4.8
MFI (20-100)*	36.8	10.6	48.2	12.4	52.0	13.5
HADS-A (0-21)*	3.8	2.5	5.5	3.3	7.1	3.6
HADS-D (0-21)*	2.4	1.9	3.3	2.3	5.3	3.1
RSES (10-40)*	34.4	3.9	32.8	4.5	30.9	5.1
GSES (10-40)*	32.0	4.1	30.9	4.2	30.9	4.2

Observed values assessed at baseline. BMI = body mass index; GSES = General Self-Efficacy Scale; HADS-A = Hospital Anxiety and Depression Scale, Anxiety part; HADS-D = Hospital Anxiety and Depression Scale, Depression part; MFI = Multidimensional Fatigue Inventory; RSES = Rosenberg Self-Esteem Scale; STAI-S = State-Trait Anxiety Inventory, State part; STAI-T = State-Trait Anxiety Inventory, Trait part; STAS-S = State-Trait Anger Scale, State part; STAS-T = State-Trait Anger Scale, Trait part. *(xx-xx) reflects the score range for that particular measurement. SD = standard deviation important sociodemographic predictors were having children (OR, 1.97; 95% CI, 1.13 to 3.63) and Dutch nationality (OR, 2.40; 95% CI, 0.76 to 9.89).

None of the medical determinants were relevant in the multivariable model. In contrast, various psychological determinants were important predictors of psychological vulnerability. Higher anxiety, aggression, fatigue, and depression scores seemed to be associated with a higher risk of psychological vulnerability after surgery (Table 3).

Model performance

The overall model performance was good (Nagelkerke's R^2, 41%; 30% after correction for optimism). The discriminative ability of the final prediction model was also promising, with an ORC of 0.80 (0.76 after correction for optimism). The Figure illustrates the practical use of the prediction model. If we aim to correctly identify 50% of those who are vulnerable, we correctly label about 90% of the non-vulnerable patients as being non-vulnerable (Figure A).

Discussion

Study results indicated that, based on the scores for the four psychological outcome parameters (i.e., anxiety, aggression, fatigue, and depression), more than one-third of our study population showed poor psychological outcomes one week after ambulatory surgery. We constructed and validated a clinical prediction model to identify these vulnerable patients. The final prediction

Table 3 Univariate and multivariable odds ratios

	Univariate		Multivariable	
	OR* (95% CI)		OR*(95% CI_b)	
Categorical variables				
Sex	1.50	(0.99 to 2.27)		
Education				
Middle	0.81	(0.46 to 1.42)	1.73	(0.88 to 4.24)
High	0.44	(0.20 to 0.94)	1.92	(0.74 to 6.18)
Employment	0.56	(0.35 to 0.89)		
Marital Status	0.72	(0.47 to 1.10)		
Children	1.35	(0.89 to 2.04)	1.97	(1.13 to 3.63)
Religion	1.45	(0.94 to 2.24)		
Nationality	0.78	(0.35 to 1.77)	2.40	(0.76 to 9.89)
Continuous variables				
Age	1.00	(0.98 to 1.01)		
BMI	1.03	(0.98 to 1.08)		
Heart rate	1.01	(1.00 to 1.03)		
STAI-S	1.07	(1.05 to 1.10)		
STAI-T	1.15	(1.11 to 1.18)	1.08	(1.03 to 1.15)
STAS-S	1.21	(1.01 to 1.45)	1.19	(0.89 to 1.62)
STAS-T	1.17	(1.10 to 1.24)	1.06	(0.97 to 1.14)
MFI	1.09	(1.07 to 1.11)	1.06	(1.03 to 1.09)
HADS-A	1.31	(1.21 to 1.40)		
HADS-D	1.43	(1.30 to 1.57)	1.17	(1.01 to 1.36)
RSES	0.87	(0.83 to 0.91)		
GSES	0.95	(0.90 to 1.00)		

Estimated values are adjusted for type of intervention as randomized, type of surgical specialty, and type of anesthesia. Multivariable model's OR (95% CI_b) for type of intervention as randomized (0=placebo; 1=lorazepam) is 1.47 (0.88 to 2.52). Used method: ordered polytomous logistic regression analysis; link function: logit. BMI = body mass index; GSES = General Self-Efficacy Scale; HADS-A = Hospital Anxiety and Depression Scale, Anxiety part; HADS-D = Hospital Anxiety and Depression Scale, Depression part; MFI = Multidimensional Fatigue Inventory; RSES = Rosenberg Self-Esteem Scale; STAI-S = State-Trait Anxiety Inventory, State part; STAI-T = State-Trait Anxiety Inventory, Trait part; STAS-S = State-Trait Anger Scale, State part; STAS-T = State-Trait Anger Scale, Trait part

*OR = odds ratio; the ORs of psychological instruments are per unit increase in the score. CI = confidence interval. CI_b, 1,000 times bootstrapped confidence interval model combined sociodemographic (i.e., level of education, having children, and nationality) and psychological determinants (i.e., trait anxiety, state/trait aggression, fatigue, and depression) and had promising overall performance and discriminative ability.

Model considerations

We developed a multivariable model with nine independent variables, four of which had statistically significant ORs. Interestingly, with respect to the psychological determinants, STAI-T (trait anxiety) was the only one of the three anxiety questionnaires (i.e., STAI-S, STAI-T, and HADS-A) included in the final prediction model. This suggests that these tests assess not only common elements but also unique elements. Furthermore, it is known that STAI-T assesses negative affectivity next to anxiety.[31]

With respect to the sociodemographic determinants, we found that level of education was somewhat paradoxically related to vulnerability. Specifically, in univariate analysis, patients with a low level of education were more likely to be vulnerable. In contrast, more highly educated patients were more likely to be vulnerable in the multivariable analysis. To exclude the possibility that this was a statistical artefact due to high correlation between determinants (i.e., multicollinearity), the variance inflation factor (VIF) should be evaluated. The VIF quantifies the degree to which multicollinearity among the determinants degrades the precision of estimate coefficients.[32] Multicollinearity negatively affects the results and the reliability of the regression estimates.[32] Generally, a VIF value exceeding 4.0 is considered to threaten valid statistical inferences. We therefore checked the multicollinearity, but we found that the VIF did not exceed 2.1. Further analyses suggested that the change in the impact of education on psychological vulnerability emerged when, in addition to demographic variables, trait anxiety was included in the prediction model. This effect was not found in analyses with the other psychological variables. One possible explanation is that patients with low levels of education are masking (i.e., giving socially desirable answers about) their anxiety, which is considered as "social desirability" in the psychological literature.[33,34] Alternatively, they may recognize their feelings of anxiety to a lesser degree –i.e., using denial as a defence mechanism. This latter psychological adjustment is well known in, for example, cancer research.[35] Furthermore, it could be that a spurious correlation emerged and that more educated patients really did have more anxiety. We emphasize that these results could be due to statistically random fluctuations.

Likewise, type of nationality turned out to be paradoxically in the analysis. Interpretations should be cautious as the Dutch nationality highly dominated the study population –i.e., our study population consisted of only 24 non-Dutch patients, making our estimate of this effect quite unstable.

Future considerations

As one-third of our study patients showed poor psychological outcome, more attention should be paid to psychological outcome parameters as clinical endpoints. Furthermore, to improve the quality of care in ambulatory surgery and to avoid negative socioeconomic effects,[6-10] patients who are vulnerable according to these psychological outcome parameters should be prepared adequately before surgery. This is a task that could be managed by anesthesiology departments, since preoperative risk assessment is a specific task of anesthesiologists, and optimizing treatment can enhance postoperative recovery.[36,37]

One method of preparing vulnerable patients could be treatment with premedication. Nevertheless, from previous studies, we know that solitary treatment with premedication, e.g., administration of benzodiazepines prior to surgery, is insufficient to improve the quality of recovery,[2,38,39] although more research is needed to clarify the effectiveness of premedication with benzodiazepines on psychological outcomes in ambulatory surgery.[40] Consequently, non-drug treatments, such as psychological preparation, seem more appropriate. In ambulatory surgery, preoperative psychological preparation could include several approaches,[41] including written, video, and/or visit information.[41] In particular, video information would provide the patient with a better understanding of the medical intervention.[42,43]

These methods could be implemented within, for example, a multimodal prehabilitation program that has physical, nutritional, and psychological aspects. The prehabilitation programs could enhance postoperative recovery using preoperative interventions tailored to the population of interest.[44-47] Because ambulatory surgical procedures are planned well in advance, a prehabilitation program could be considered to treat these vulnerable patients. Currently, however, there is a lack of prehabilitation programs for ambulatory surgery.

Such methods could also be adjusted and tailored to the postoperative period and perhaps incorporated into the rehabilitation program. Rehabilitation programs are multimodal programs that predominantly intervene in the postoperative period to enhance postoperative outcome.[48] Such programs have been shown to be effective in different surgical populations.[48-50] It has also been suggested that rehabilitation programs should be reserved for patients who require postoperative care after the prehabilitation program.[47]

If these multidisciplinary prehabilitation and rehabilitation programs are implemented, anesthesiologists should play a prominent role in their management.[51] Development of a risk stratification model is highly recommended so that the program could be tailored to different sets of patients.[44] Using our prediction model, risk stratification for the ambulatory population may become feasible, and stratification could guide decision-making. Presumably, patients identified as single-domain vulnerable would need a different treatment plan than those identified as multiple-domain vulnerable. The Appendix illustrates the clinical application of the constructed clinical prediction model for two clinical cases.

There should be further investigation as regards the clinical importance of these findings in terms of the identified vulnerabilities. Additional research is also needed to investigate which treatment is required for vulnerable patients; furthermore, a cost-effectiveness analysis should be performed.

Using this prediction model requires some effort, and therefore, future studies could be tailored to minimize this effort. Future studies could also investigate whether determinants associated with "bad" habits (e.g., smoking, alcohol and drug usage, excessive eating, sedentary lifestyle, etc.) are manifestations of psychological vulnerability. It would also be interesting to investigate the influence of interpersonal variables, since previous research shows that these variables are also important care characteristics.[52] In addition, preoperative mental health screening could be considered, especially with regard to more severe (surgical) populations. One essential step is to acquire external validation for our model in independent sets of patients, which may indicate the need for modifications.[32]

Study limitations and strengths

Our study has some limitations. First, 15 patients were not analyzed due to lack of outcome data. These patients could be vulnerable and therefore unable to complete the measurements one week after surgery. Second, in the original RCT, patients were excluded due to use of psychopharmaceuticals or because they were undergoing certain surgical procedures, e.g., abortion, which were stressful for these patients.[2] It is plausible that these patients may be more susceptible to the psychological events that could be elicited by a surgical procedure. Therefore, we expect that the actual percentage of vulnerable patients in ambulatory surgery may be higher than 36%. This does not imply that the final prediction model should be changed accordingly. Finally, this was a single-centre study, and the generalizability of the model needs to be studied.

The main strength of our study is that it uses high-quality data from a randomized trial. In addition, we internally validated our prediction model. Detection of vulnerability was based on tests that are all psychometrically validated in psychomedical fields. Therefore, we do not assume that we have necessarily underdiagnosed vulnerability in this surgical population.

Conclusion

This study identified a substantial group of vulnerable patients in ambulatory surgery. The proposed clinical prediction model is a first step in predicting poor psychological outcome after ambulatory surgery, although additional modification and validation are needed. The model could allow healthcare professionals, especially anesthesiologists, the opportunity to identify vulnerable patients in ambulatory surgery who would benefit from specific interventions.

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Appendix

In this manuscript, we constructed the following clinical prediction model:

$$Y = \beta_0 + \beta_{Educ1} \times \text{Educ1} + \beta_{Educ2} \times \text{Educ2} + \beta_{Children} \times \text{Children} + \beta_{Nationality} \times \text{Nationality} + \beta_{STAI-T} \times \text{STAI - T} + \beta_{STAS-S} \times \text{STAS - S} + \beta_{STAS-T} \times \text{STAS - T} + \beta_{MFI} \times \text{MFI} + \beta_{HADS-D} \times \text{HADS - D}$$

$\beta_0 = 10.223$ (threshold 0) or 11.823 (threshold 1)

$\beta_{educ1} = 0.546$; $\beta_{educ2} = 0.653$; $\beta_{Children} = 0.676$; $\beta_{Nationality} = 0.876$; $\beta_{STAI-T} = 0.078$; $\beta_{STAS-S} = 0.177$; $\beta_{STAS-T} = 0.059$; $\beta_{MFI} = 0.057$; $\beta_{HADS-D} = 0.153$

Application clinical prediction model – Case 1

Miss X, born at 01-02-1970 in Rotterdam where she has been living. She has been married and gave birth to two children. She completed primary school only. Preoperatively, she showed the following results on the questionnaires:

STAI-S	25
STAI-T	23
STAS-S	12
STAS-T	10
MFI	30
HADS-A	3
HADS-D	5
GSES	35
RSES	35

Her estimated risk of being non-vulnerable, single vulnerable, and multiple vulnerable is equal to 84%, 12%, and 4%, respectively.

Application clinical prediction model – Case 2

Mr Y, born at 03-04-1972 in Rotterdam where he has been living. This single man has no children. He graduated from university and works as a lawyer. Preoperatively, he showed the following results on the questionnaires:

STAI-S	4025
STAI-T	45
STAS-S	17
STAS-T	12
MFI	40
HADS-A	12
HADS-D	10
GSES	15
RSES	20

His estimated risk of being non-vulnerable, single vulnerable, and multiple vulnerable is equal to 9%, 23%, and 68%, respectively.

Children = having children; Educ1 = middle level of education; Educ2 = high level of education; HADS-D = Hospital Anxiety Depression Scale, Depression part; MFI = Multidimensional Fatigue Inventory; Nationality = type of nationality; STAI-T = State-Trait Anxiety Inventory, Trait part; STAS-S/T = State-Trait Anger Scale, State/Trait part.

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