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Predicting post-surgical cognitive disturbance in older Taiwanese patients

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Abstract

The purpose of this study was to test a theoretical model to understand the influences of six predicting variables in post-surgical cognitive disturbance in older Taiwanese patients after elective surgery. The data were collected in a medical center in Taipei, Taiwan. Ninety-three patients were included in the final analysis. The findings showed that cognitive function at admission ($\beta = 0.50$, $p < 0.001$), physical function at admission ($\beta = -0.34$, $p < 0.001$), and physiological stability ($\beta = -0.21$, $p < 0.01$) had direct effects on post-surgical cognitive disturbance. Physical function and cognitive function at admission also affected post-surgical cognitive disturbance indirectly through physiological stability. These variables accounted for 67% of the total variance of post-surgical cognitive disturbance. The findings from this study suggest that a careful and systematic assessment of the patient's condition at the time of admission is important. It is necessary to monitor and correct these variables at admission or before surgery to prevent or reduce the impact of post-operative delirium. It is also necessary to monitor these variables during the hospital stay to help nurses to distinguish the etiology of delirium. In each case, knowing when confusion is more likely to occur can assist in focusing more appropriate and effective efforts at detection, thereby reducing the consequences associated with confusion.

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1. Introduction

Acute confusion or delirium is an indicator of cognitive disturbance and is a significant health problem for the hospitalized elderly (Rudberg et al., 1997; Smita et al., 1995). The reported incidence of delirium in acutely ill elderly patients during hospitalization ranges from 7% to 73.5% (Dyer et al., 1995; Foreman et al., 2001; Francis, 1992; Francis et al., 1990; Inouye & Charpentier, 1996; Marcantonio et al., 2000; Mentes et al., 1999; O'Keeffe & Lavan, 1997; Smita et al., 1995).

In elderly patients, delirium is often an early indicator of pathophysiological and psychological disturbances. If delirium goes undetected or untreated, the patient's cognitive function, well-being, and even chances of survival can become seriously threatened (Foreman et al., 2001; Francis et al., 1990; Smita et al., 1995). In most cases, delirium due to a medical disease is reversible with treatment of the underlying condition (Espino et al., 1998; Francis, 1992; Gomez and Gomez, 1989).

Cognitive disturbance is complex and multidimensional. Research in the last two decades has identified several precipitating and host-related factors for cognitive disturbance (delirium) in a variety of settings and populations (Francis et al., 1990; Inouye and Charpentier, 1996). These factors are complex and inter-related. However, most of the studies focused mainly on risk

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factors and precipitating factors. Few studies have tested theories that integrate the potential influences of several personal and physiological factors on cognitive disturbance.

This study has developed a theoretical model for testing post-surgical cognitive disturbance. The aim of this study was to test a theoretical model represented in Fig. 1 to understand the influences of six predicting variables in post-surgical cognitive function in older Taiwanese patients after elective surgery. These six variables are placed in four stages by sequential order during the hospital stay. The predicting variables are age, cognitive function at admission, physical function at admission, physiological stability, surgical stress and psychoactive medication use. The outcome variable is the severity of post-surgical cognitive disturbance. The model proposes that (1) age, physical function at admission, cognitive function at admission, physiological stability, surgical stress and psychoactive medication used have direct effects on the severity of post-surgical cognitive disturbance, and (2) age, physical function at admission, cognitive function at admission, also have indirect effects through two peri-operative variables—physiological stability and surgical stress on the severity of post-surgical cognitive disturbance.

In the following literature review, post-surgical delirium as a cognitive disturbance is the focus of this review.

1.1. Stage I variable: age

Aging involves an increasing vulnerability to physiologic, psychological and sociocultural insult. Age has been identified as the major risk factor for cognitive disturbance in many reports. Cognitive disturbance is the one condition that increases consistently with advancing age (Dai et al., 2000; Marcantonio et al., 1994; Martin et al., 2000; McDougall, 1995; Schor et al., 1992; Williams-Russo et al., 1992; Zelinski et al., 1998). It was also reported that age correlated negatively with an individual's functional ability (Patrick, 1993; Resnick and Daly, 1998). Multiple potential risk factors correlate with increasing age. The two main physiological effects of aging that increase elderly people's chances to become cognitively impaired are (1) reduction of the brain's ability to adapt to metabolic abnormalities (Mast, 1996), (2) lowered body water content and a higher proportion of fatty tissue that reduces renal perfusion (Fretwell, 1993). During surgery, the loss of blood or body fluid exacerbates this condition. It is common to use IV fluid therapy after surgery, which may cause overhydration and dilutional hyponatremia, which further develops confusion in the elderly patients.

For medication used, it is estimated that elderly patients consume 25% to 40% of all prescription drugs and average 4.5 prescriptions daily, primarily because of multiple chronic diseases (DeMaagd, 1995). Alterations in pharmacokinetic action with aging and multiple drug

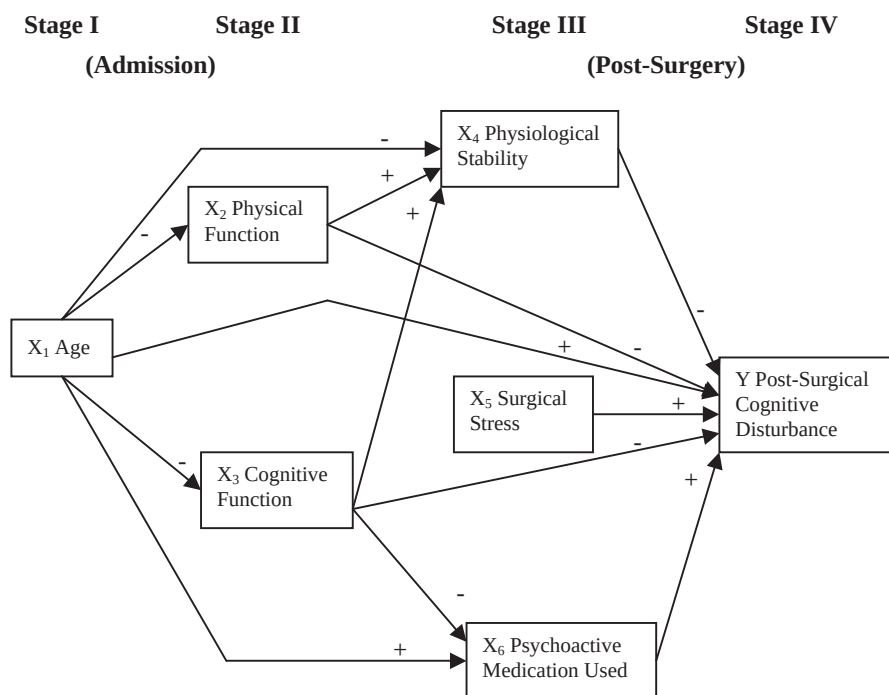


Fig. 1. Theoretical model of predictors of post-surgical cognitive disturbance in older Taiwanese patients after elective surgery.

use or misuse increase the possibility of drug reactions and drug interactions associated with cognitive disturbances or other serious consequences (DeMaagd, 1995; Robert and Lincoln, 1988).

1.2. Stage II variable: physical function

Physical function is a precipitating factor for cognitive disturbance among elderly patients (Dai et al., 2000; Marcantonio et al., 1994; Milisen et al., 1998; Schor et al., 1992; Zelinski et al., 1998). Milisen et al. (1998) reported a relationship between functional status and cognitive function. Patients with decreased cognitive status post-operatively had reduced physical performance compared to non-impaired patients. From a large survey data set, Zelinski et al. (1998) reported that the presence of stroke, diabetes and poorer health ratings predicted poorer performance on recall and mental status tasks. Age interacted with medical conditions including high blood pressure and diabetes in predicting mental status. They concluded that chronic physical conditions were associated with cognitive deficits.

The individual with poor physical function may lead to poor cognitive performance and vice versa. The person who developed delirium post-surgery was associated with poor functional recovery 1 month after fracture (Marcantonio et al., 2000). Dolan et al. (2000) reported similar findings up to 24 months post-surgery. In Royall et al.'s (2000) study, they reported the individual's cognitive function had significantly affected the level of IADL function. Knight (2000) reported that cognition is one key dimension of functional status. One must "know what to do" to perform to be successful in an activity which required choosing, attending, and problem solving.

1.3. Stage II variable: cognitive function

Individuals who are cognitively impaired suffer major adverse consequences from illness (McDougall, 1995; Robert and Lincoln, 1988). Also, individuals who are cognitively impaired suffer major adverse consequences from illness (McDougall, 1995; Robert and Lincoln, 1988). Pre-operative poor performance on cognitive testing was one of the predictors for delirium development post-surgery (Williams et al., 1985). Similar results were reported from Dai et al. (2000), Francis et al. (1990), Gustafson et al. (1988), Marcantonio et al. (1994), Pompei et al. (1994), and Schor et al. (1992).

From the literature, psychoactive medication use is a precipitating factor for delirium development (Dai et al., 2000; Francis et al., 1990; Gustafson et al., 1988; Inouye and Charpentier, 1996; Martin et al., 2000; Rudberg et al., 1997; Schor et al., 1992). However, it was often difficult to establish whether psychoactive drugs were causing the delirium or whether the drugs were

prescribed after the symptoms of delirium appeared (Tune, 1991). The hypothesis for this study is that the less cognitive function pre-surgical patients have the greater the amount of post-surgical psychoactive medication use, further worsening the individual's cognitive function.

1.4. Stage III variables: physiological stability

Delirium has been identified with many physiological indicators (Bruera et al., 1995; Cosgray et al., 1993; Elmstahl et al., 1995; Francis et al., 1990; Inouye et al., 1993; Koizumi et al., 1988; Menten et al., 1999). Fluid and electrolyte imbalance, especially hypo-, or hypernatremia and hypo- or hyperkalemia, is the third most common cause of acute confusion; metabolic disturbance is the fourth most common cause (Bruera et al., 1995; Foreman and Zane, 1996). Metabolic risk factors have been identified in some of the research (Elmstahl et al., 1995; Francis et al., 1990; Marcantonio et al., 1994). These metabolic disturbances included abnormal sodium, potassium or glucose level, elevated BUN and blood creatinine. Some reports have suggested that fever, infection and dehydration can induce delirium also (Inouye and Charpentier, 1996). The physiological changes of aging and the research results support that these electrolyte and biochemical indicators are important variables to monitor for delirium patients.

1.5. Stage III variable: surgical stress

Surgery and anesthesia also have the potential for neurological insults to elderly patients (Jagmin, 1998). Martin et al. (2000) reported surgery was one of the risk factors for delirium development during hospitalization. For surgical treatment, literature revealed that the type of surgery, blood transfusion, and anesthesia affect the cognitive functioning of the elderly post-operatively (Dai et al., 2000; Berggren et al., 1987; Marcantonio et al., 1994). From the review of Ritchie et al. (1997), cognitive disorder varies according to the type of surgery, with rates of 0–44% being reported for ophthalmic surgery, 25–48% for orthopedic surgery, and more than 80% for cardiac surgery.

Anesthesia has been identified as one of the precipitating factors in post-operative delirium (Berggren et al., 1987; Lipowski, 1990). Medications used to produce and maintain anesthesia are known to act both directly on the central nervous system and indirectly by causing anoxia through depression of the respiratory system (Ritchie et al., 1997). However, several authors reported that the type of anesthesia does not affect the magnitude or pattern of post-operative cognitive disturbance in older adults undergoing elective surgery (Berggren et al., 1987; Dyer et al., 1995; Stromberg et al., 1997; Williams-Russo et al., 1992). They reported that

other factors such as the stress of the surgical procedure, and the prolonged recovery period were stronger contributors to delirium than the type of anesthesia (Williams-Russo et al., 1992, 1995). Whether or not type of anesthesia may be an important factor for post-surgical cognitive disturbance is still uncertain. In this theoretical model, it is assumed that general anesthesia will induce cognitive disturbance.

1.6. Stage III variable: psychoactive medication used

Many drugs and drug combinations have been associated with acute onset of delirium. Literature has suggested that an etiologic relationship exists between decreased levels of neurotransmitters in the brain, such as acetylcholine, and delirium (Jacobson, 1997; Parente and Herrmann, 1996; Smita et al., 1995). Impairment of the cholinergic-activating pathways results in disorder of the arousal, alertness, and sleep states. Thus, treatment with drugs that affect cholinergic pathways and interfere with arousal or alertness and sleep cycles, or that alter the concentrations of neurotransmitters in the central nervous system increase the risk of delirium (Berggren et al., 1987; Gustafson et al., 1988; Levkoff et al., 1991; Smita et al., 1995; Tune et al., 1993). Rudberg et al. (1997) reported that medication is the leading cause for delirium for medical-surgical elderly patients. Other researchers reported that use of multiple medications (Inouye & Charpentier, 1996; Martin et al., 2000), narcotics or sedatives (Francis et al., 1990), neuroleptic or narcotics (Schor et al., 1992), alcohol (Marcantonio et al., 1994; Pompei et al., 1994; Williams-Russo et al., 1992), and psychoactive drugs (Dai et al., 2000) precipitated delirium development.

From the literature review, a theoretical model has been developed that includes six predictors affecting post-surgical cognitive function and their interrelationships. These six predictors all impact the severity of post-surgical cognitive disturbance. The literature presented supports the variables related to post-surgical cognitive disturbance and the complexity of the interrelationship of these variables, but it is inconclusive whether these variables are causes, effects or just simply correlate to cognitive disturbance. However, these variables can be placed in sequential order during the hospital stay.

2. Method

This study used secondary data from a previous study about confusion in the hospitalized elderly Taiwanese patients (Dai et al., 2000). The original data were collected in the orthopedic and urological units of a 2000-bed medical center in Taipei, Taiwan. The inclusion criteria for this study were (1) 65 years of age or

older; (2) ability to communicate orally in Chinese; (3) not unconsciousness, delirious, deaf, or aphasic on admission. A trained research assistant (RA) who was a registered nurse collected the data. Potential participants were approached and the purpose of the study was explained with 24 h of admission. They were assured of confidentiality, anonymity, and the freedom to withdraw from the study at any time. The detailed procedures have also been described in Dai et al. (2000). Eight hundred and one patients consented to participate to this study. Among the 801 patients, 106 patients were closely observed during their post-operative period. Among these 106 patients, 41 patients developed post-surgical delirium and confirmed by DSM-IV criteria for delirium (American Psychiatric Association, 1994). In this paper, the 106 patients' data which included the admission functional status, admission and post-surgical mental assessment data, selected laboratory data and medication administered, were used to test a theoretical model of post-surgical cognitive disturbance.

2.1. Sample

One hundred and six patients were included in the analysis.

2.2. Measures

2.2.1. Age

The patients' chronological age was used in the model testing.

2.2.2. Physical function

The Barthel Index was used to measure an individual's function in performing activities of daily living (ADL) at admission. This index contains ten items with a maximum score of 100, which indicates total independence in ADL (Mahoney and Barthel, 1965; Resnick and Daly, 1998). The reported inter-rater reliability (Kappa coefficient) ranged from 0.70 to 0.88 (Loewen and Anderson, 1988; Richards et al., 2000). The Barthel Index certainly has "face validity" because it covers items usually included in ADL indices. Factor analysis, which represents construct validity, has confirmed that it is measuring a single domain (Wade and Collin, 1988). These reports support the reliability and validity of the index.

2.2.3. Cognitive function

The MMSE was used to assess the cognitive function of the patients. The MMSE was developed by Folstein et al. (1975) from clinical observations of patients. The MMSE has been translated into Chinese with a small amount of modification based on sociocultural differences of the Chinese population (Katzman et al., 1988). This exam consists of 30 dichotomous items with a total

score of 30. A score of less than 24 indicates cognitive impairment. A score of 18–23 indicated mild cognitive impairment and, 0–17 indicates severe cognitive impairment (Dolan et al., 2000; Tombaugh and McIntyre, 1992). The reported test–retest reliability was 0.56–0.98. Inter-rater reliability was 0.82. Internal consistency was 0.96. Criterion-related validity was 0.78. The sensitivity was 0.87 and the specificity was 0.82 (Folstein et al., 1975; Tombaugh and McIntyre, 1992). The instrument demonstrates satisfactory reliability, construct validity, and criterion validity.

2.2.4. Surgical stress

Three indicators regarding surgical treatments were selected in this study as a risk index to test the theoretical model. These included types of surgery, types of anesthesia and blood transfusion. These items were coded as “yes” or “no.” The total score ranges from 0 to 3. The higher the score, the more risk for cognitive impairment the individual would have after surgery.

2.2.5. Physiological stability

Six indicators regarding physiological stability were used in this study to test the theoretical model. These include blood sodium (Na), potassium (K), blood urea nitrogen (BUN), fasting blood glucose (BSAC), body temperature (BT) as fever and infection indicator, and the ratio of BUN to creatinine as a dehydration indicator (BUN/Cr.). The subject's most recent test values obtained during his/her hospital stay were used in the analysis. From the suggestion of literature (Davis, 1993), the following cutoff point was used: Na, 135–146 mmol/l, K, 3.0–5.9 mmol/l, BUN, 9–33 mg/dl, BSAC, 70–110 mg/dl, BT, $< 37.7^{\circ}\text{C}$ (99.8°F), BUN/Cr., < 18 . The data were coded as normal vs. abnormal based on the cutoff point. The total score ranges from 0 to 6. The higher the score, the more stable the physiological condition of the individual.

2.2.6. Psychoactive medication used

A checklist of 26 medications with psychoactive action was used to record whether these medications were used during post-surgical period. The list included those medications indicated in the literature to be significantly related to delirium such as morphine, meperidine, atropine, etc. (Marcantonio et al., 1994; Smita et al., 1995). In data analysis, the medications were categorized into five types: narcotic analgesics, sedative hypnotics, histamine 2-receptor blockers, anti-Parkinsonism agents, and anti-cholinergic drugs. The total score ranges from 0 to 5. The higher the score, the more psychoactive medication was used.

2.2.7. The outcome variable: severity of cognitive disturbance

The mental status, which was assessed by the MMSE, was used as the outcome variable. Patients were categorized on the basis of post-surgical cognitive status into three levels as follows: no cognitive impairment ($\text{MMSE} > 24$), moderate ($\text{MMSE} < 23$ but > 18) and severe impairment ($\text{MMSE} < 17$). The higher the level, the more severe the cognitive impairment (Dolan et al., 2000; Milisen et al., 1998; Tombaugh & McIntyre, 1992).

2.3. Data analytic procedure

The analysis include (1) case-related issues such as the accuracy of data input, missing data, and outliers, (2) distributional relational issues such as normality, linearity, and homoscedasticity, and (3) regression analysis to test for each path in the model.

Data sets with absolute values of univariate skew indexes greater than 1.96 were extremely skewed (Duffy and Jacobsen, 2001). These data were transformed. The Correlation matrix was used to present the correlation of the variables. Multicollinearity occurs when inter-correlations among some variables are so high that certain mathematical operations are either impossible or the results are unstable because some denominators are very close to zero. The variance inflation factor (VIF) was used as the index of multicollinearity among predicting variables. The VIF is the ratio of a variable's total variance in standardized terms to its unique variance. If the ratio is greater than 10, then the variable may be redundant with others (Kline, 1998). Standardized regression coefficients (β) were used to present the final result. Path coefficients were considered meaningful if they are statistically significant ($p < 0.05$). Adjusted R^2 ($\text{Adj. } R^2$) was used to present the total variance explained by the independent variables to the outcome variable.

3. Results

3.1. Description of the subjects and univariate analysis of the major variables

One hundred and six subjects were in the data set. The data were entered into an SPSS data file. Upon inspection of the data matrix, it was noted that four subjects did not complete the MMSE and another nine did not have the complete biochemistry data for analysis. Therefore, a total of 93 subjects with complete data were used to test the model. Univariate analysis on demographic variables showed the ages of the study sample ranged from 65 to 93 years of age with a mean of 74.3 and standard deviation (SD) of 6.5. The number of

male (46, 49.5%) and female (47, 50.5%) subjects were almost equal. The majority of the subjects (76.3%) were literate. The average year of education was 6.9 years ($SD=5.3$). Most of the subjects (80.6%) received orthopaedic surgery.

Table 1 presents the frequency for items in the major variables. Six items combined to represent the subject's physiological stability. Of these subjects, 98% had normal blood potassium level, but only 54% had normal blood glucose. Three items combined to represent the subject's level of surgical stress. Most of the subjects received spinal anesthesia (72%), had blood transfusion (90%) and orthopaedic surgery (81%). Five items combined to represent the amount of psychoactive medication used by the subject. Of these subjects, 73% of subjects had narcotics and 31% had sedative hypnotic post-surgery. Table 2 presents the descriptive analysis of the major variables. The mean age of these subjects was 74.3 years ($SD=6.5$). The mean of the Barthel ADL total score, indicating the subject's physical function, was 89.46 ($SD=23.06$). The mean of the MMSE total score, indicating the subject's cognitive function, was

25.41 ($SD=5.28$). The mean scores of physiological stability and surgical stress were 4.7 ($SD=1.06$), 2.0 ($SD=0.79$), respectively. On average, the subjects used 1.33 ($SD=0.93$) types of psychoactive medication post-surgery.

While examining the distribution of the major variables and their skewness indexes (Table 2), the scores of physiological stability, and psychoactive medication used were shown to have normal distribution. The distribution of age was slightly positively skewed, indicating a higher number of younger subjects in this sample. The score of surgical stress was slightly negatively skewed, indicating that more subjects had high scores on surgical stress. The total Barthel ADL score and the total MMSE score were negatively skewed. The skewness indexes were -11.08 and -5.36 , respectively. This skewness indicates that more subjects had high scores in these two variables. These two variables were transformed by the suggestions of Tabachnick and Fidell (Tabachnick and Fidell, 1996). The logarithm transformation was applied to transform the admission total MMSE score (New score = LG_{10}

Table 1
Univariate analysis of items in major variables of the model ($N=93$)

Variable	<i>N</i>	%	Variable	<i>N</i>	%
<i>Physiological stability</i>			<i>Psychoactive medication used</i>		
K			Narcotics		
Normal	91	97.8	Yes	68	73.1
Abnormal	2	2.2	No	25	26.9
Na			Sedative-hypnotic		
Normal	78	83.9	Yes	29	31.2
Abnormal	15	16.1	No	64	68.8
BUN			Histamine blocker		
Normal	81	87.1	Yes	13	14.0
Abnormal	12	12.9	No	80	86.0
Glucose			Anti-parkinsonism		
Normal	50	53.8	Yes	1	1.1
Abnormal	43	46.2	No	92	99.9
Dehydration			Anti-cholinergics		
Normal	54	58.1	Yes	13	14.0
Abnormal	39	41.9	No	80	86.0
Body temperature					
Normal	81	87.1			
Abnormal	12	12.9			
<i>Surgical stress</i>					
Anesthesia					
General	26	28.0			
Spinal	67	72.0			
Blood transfusion					
Yes	84	90.3			
No	9	9.7			
Type of surgery					
Orthopaedic	75	80.6			
Urological	18	19.4			

Table 2
Univariate analysis of major variables in the model ($N = 93$)

Variable name	No. of items	Possible range	Actual range	Mean	SD ^a	Skewness index ^b
X_1	1	65 and above	65–93	74.33	6.54	3.11
Age						
X_2	10	0–100	0–100	89.46	23.06	–11.08
Physical function at admission by Barthel index						
X_3	30	0–30	6–30	25.41	5.28	–5.36
Cognitive function at admission by the MMSE						
X_4	6	0–6	2–6	4.68	1.06	–2.13
Physiological stability						
X_5	3	0–3	0–3	1.99	0.79	–2.66
Surgical stress						
X_6	5	0–5	0–4	1.33	0.93	1.17
Psychoactive medication used						
$X_{2,1}$		0.01–1	0.01–1	0.66	0.45	–2.36
Transformed of physical function at admission						
$X_{3,1}$		0–1.49	0–1.40	0.55	0.43	0.51
Transformed of cognitive function at admission						
Y		1–3	1–3	1.70	0.89	2.55
Severity of post-surgical cognitive disturbance						

^aSD, standard deviation.

^bSkewness index = skewness/standard error of skewness.

Table 3
Bivariate correlation of the major variables ($N = 93$)

Variable	X_1	$X_{2,1}$	$X_{3,1}$	X_4	X_5	X_6	Y
X_1	1.00						
$X_{2,1}$	–0.45**	1.00					
$X_{3,1}$	–0.42**	–0.44**	1.00				
X_4	–0.07	0.34**	–0.30**	1.00			
X_5	–0.09	–0.27	0.10	–0.39**	1.00		
X_6	0.06	0.25*	0.07	0.18	0.29**	1.00	
Y	0.39**	–0.64**	0.72**	–0.48**	0.23*	0.15	1.00

* $p < 0.05$, ** $p < 0.01$.

X_1 : age, $X_{2,1}$: transformed total Barthel ADL score at admission, $X_{3,1}$: transformed total MMSE score at admission, X_4 : physiological stability, X_5 : surgical stress, X_6 : total psychoactive medication used, Y : severity of post-surgical cognitive disturbance.

(31-old score). After logarithm transformation, the original higher scores of the MMSE converted to lower new scores, thus changed the sign (+, –) of paths of this variable in the theoretical model. The inverse transformation was applied to transform the total Barthel score (New score = $1/(101 - \text{Old score})$). After transformation, the original higher scores of the Barthel score converted to higher new scores, thus, the sign of this variable kept the same in the theoretical model. After transformation, the skewness indexes for these two variables were 0.51 and –2.36, respectively (Table 2). The transformed data were used for further analysis.

3.2. Bivariate correlation among variables of the model

Zero order correlations among these seven variables in the theoretical model were presented in Table 3. All the dependent variables, except the score of psychoactive medications used, were significantly correlated with the outcome variable. The correlation coefficients ranged from 0.15 to 0.72 among these variables. One strong correlation (correlation coefficient higher than 0.65) and five moderate correlations (correlation coefficients between 0.40 and 0.65) were found from the major variables. When independent variables were highly correlated to each other, researchers should be cautious

to use them in the same analysis. The problem of multicollinearity could occur (Tabachnick and Fidell, 1996), which would make multivariate regression analysis inappropriate. While looking at the squared multiple correlation (R^2) or tolerance ($1 - R^2$) among independent variables, they showed that multicollinearity is not a problem. A very low value of tolerance indicates multicollinearity among variables. The tolerance of these independent variables ranged from 0.61 to 0.88. This tolerance means only 0.12–0.39 of variance is shared by other independent variables.

The scatterplots of residuals of dependent variables were used to examine the assumptions of normality, linearity, and homoscedasticity of residuals. Scatterplots of all variables showed a spread out distribution of the residuals against the expected values. Thus, the assumption was met on all major variables.

3.3. Testing of the theoretical model by path analysis

Fig. 2 showed the path coefficients for the theoretical model. Seven out of the 13 paths were significant at $p < 0.05$ or $p < 0.001$ level. These six predictors explained 66.0% of the total variance in subjects' post-surgical cognitive disturbance. Age strongly predicted physical function ($\beta = -0.45$, $p < 0.001$) and cognitive function at admission ($\beta = 0.42$, $p < 0.001$) for the Stage II variables. The more advanced in age that subjects were, the less

physical function and cognitive function was preserved. Physical function and cognitive function at admission, but not the age, significantly predicted the severity of post-surgical cognitive disturbance directly ($\beta = -0.34$, 0.50 , respectively, $p < 0.001$). Subjects more cognitively intact and physically functional at admission were less cognitively impaired after surgery. For the stage III variables, physical function and cognitive function had direct effects on physiological stability ($\beta = 0.32$, -0.23 , $p < 0.01$, 0.05 , respectively). These two variables explained 14% of variance in physiological stability. Cognitive function and age had no significant impact on psychoactive medication used. Physiological stability directly predicted the severity of post-surgical cognitive disturbance ($\beta = -0.21$, $p < 0.01$). Individuals more physiologically stable were less affected by post-surgical cognitive disturbance. However, the surgical stress and psychoactive medication used had no significant impact on post-surgical cognitive disturbance.

When the insignificant paths were deleted and the regression analysis was run again from the original empirical model, 67.0% of total variance in subjects' post-surgical cognitive disturbance was accounted for in the reduced model (Fig. 3). Age, physical and cognitive functions at admission, and physiological stability were the four significant predictors for the severity of post-surgical cognitive disturbance. Age had direct effect to

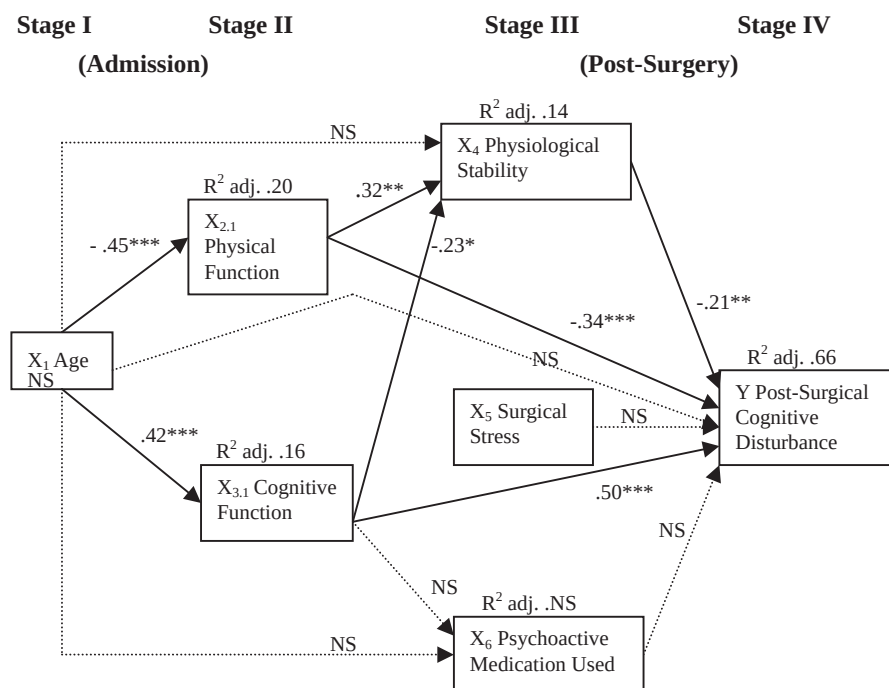


Fig. 2. Standardized regression (path) coefficients for the original empirical model ($N = 93$). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. ---; non-significant path, NS; non-significant.

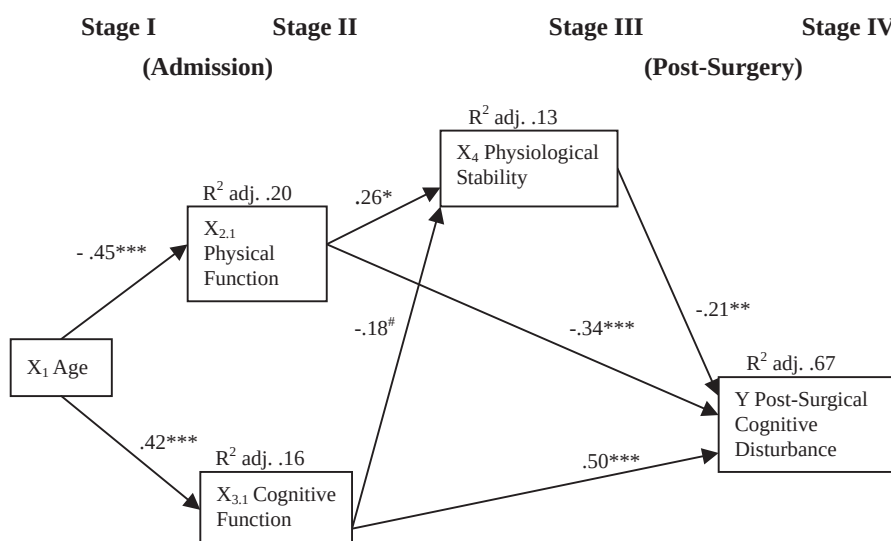


Fig. 3. Reduced empirical model for predicting severity of post-surgical cognitive disturbance ($N = 93$). # $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

physical function and cognitive function. Physical function and cognitive function affected post-surgical cognitive disturbance directly, also indirectly through physiological stability.

4. Discussion and conclusions

As hypothesized, the subjects' physical function and cognitive function had direct effects on post-surgical cognitive disturbance. Physical function and cognitive function also had indirect effects on post-surgical cognitive disturbance through physiological stability. These findings are supported from the literature such as the works of Gustafson et al. (1988), Francis et al. (1990), Schor et al. (1992), Pompei et al. (1994), Marcantonio et al. (1994), McDougall (1995), and Dai et al. (2000).

In this study, physiological stability was a significant predictor for post-surgical cognitive disturbance. The items for physiological stability in this study were blood sodium, blood potassium, blood urea nitrogen, blood glucose, body temperature and dehydration index. This finding was also supported by the literature. From the literature, electrolyte imbalance and metabolic disturbances have been identified as major precipitating factors for delirium (Elmstahl et al., 1995; Foreman and Zane, 1996; Francis et al., 1990; Koizumi et al., 1988; Marcantonio et al., 1994). These disturbances included abnormal sodium, potassium or glucose levels, elevated BUN and blood creatinine. Besides these, some reports suggested that fever, infection and dehydration

can induce delirium (Cosgray et al., 1993; Inouye and Charpentier, 1996; Inouye et al., 1993; Mentes et al., 1999). Most of the studies recorded these physiological indicators as background information and tested them as risk factors for delirium. These physiological variables were significantly associated with the onset of delirium, but it is impossible to conclude whether these variables are causes, effects or just simply correlates of delirium. Among the researchers, Marcantonio et al. (1994) indicated the admission biochemistry data significantly predicted further delirium for surgical patients. From the literature, it is indicated that either admission biochemistry data or random biochemistry data during the hospital stay correlated to the development of delirium. During the model testing in this study, use of the biochemistry data also showed significant effects on the post-surgical cognitive disturbance. The findings support previous research results. In the current study, the records of indicators were selected from the literature as the most important physiological indicators for delirium. They were recorded from subjects' medical records. Although some of the biochemistry data were not available in the data set; this missing data represents the complex nature of everyday practice.

The physiological change of aging and the research results support that these electrolyte and biochemical indicators are important variables to monitor for delirium patients. A careful and systematic assessment of the patient's condition at the time of admission is important. It is necessary to monitor and correct these variables in admission or before surgery to prevent or reduce the potential for the post-surgical cognitive

disturbance. It is also necessary to monitor these variables during the hospital stay to help distinguish the etiology of delirium. In each case, knowing when confusion is more likely to occur can provide more appropriate and effective efforts at detection, thereby reducing the consequences associated with confusion.

Psychoactive medication used and surgical stress did not have a significant effect on post-surgical cognitive disturbance. Psychoactive medications or multiple medication has been reported as a major predictor for cognitive disturbance (Dai et al., 2000; Francis et al., 1990; Gustafson et al., 1988; Inouye and Charpentier, 1996; Martin et al., 2000; Rudberg et al., 1997; Schor et al., 1992). In the current study, a total of 26 medications were analyzed. In the literature these medications were thought to be significantly related to delirium. In data analysis, the medications were categorized into five types. They were recorded as “yes” indicating that the subjects used this type of medication and “no” indicating that the subjects did not use this type of medication. There was no prescription dosage or duration information available for the analysis. Whether subjects used a small amount or large amount, or one dose or 10 doses of a medication did not matter; medication in any amount was given the same value. This variability may be the reason that psychoactive medication did not show a significant effect on post-surgical cognitive disturbance. Some studies (Mach et al., 1995; Miller et al., 1988) transformed the serum anticholinergic level of the medication into atropine-equivalent level. This might be a better strategy to measure the medication effects for future research.

In this study, three items were selected to the variable of “surgical stress”: type of anesthesia, type of surgery, and blood transfusion. Other indicators about surgical stress were not available for this secondary data analysis. Since only three items were used in this analysis, it may have been an unstable variable. Also, from the literature, different types of anesthesia may be an important factor for post-surgical cognitive disturbance. However, this is still uncertain. Some possible explanations of why the anesthesia had no effect were raised. These explanations included the postoperative cognitive decline, the existed pre-surgery undiagnosed neuropsychiatric disorders that continue to follow their course post-surgery; pre-operative physical condition; alteration in cerebral blood flow and metabolism due to factors other than anesthesia; and the medication given in conjunction with anesthesia (Ritchie et al., 1997). From the current study, the majority of subjects received spinal anesthesia (72%), had orthopaedic surgery (81%), and had a blood transfusion (90%). It was a relatively homogeneous group. By combining these indicators, the variations of the scores for this variable may decrease due to the similar treatment that they received during surgery. This may be one of the reasons

that surgical stress did not have a direct effect on post-surgical cognitive disturbance in the current study.

4.1. Implications

Delirium has multiple etiologies. Both chronic and acute conditions contribute to risk of delirium. For early detection and prevention of further damage, cognitive assessment and physical assessment should be included as a routine procedure. Acquiring baseline data about mental status at the time of admission by standardized assessment instruments is relevant and should be included in nursing care plans of elderly patients. Patients at risk should also be closely monitored for clinical features of cognitive disturbance to make it possible for early detection and management. To achieve this outcome, a tool that is valid and reliable, easy administer, and less strenuous for patients is needed for the actual clinical setting for cognitive assessment. Also, early detection and management procedures can be taught during in-service nursing education. The results can also be used for in-service nursing education to stress the importance of mental state examination, physical function assessment and the biochemistry indicators during the patient's admission and hospital stay.

The followings are recommendations for future research:

- (1) Re-testing the model with different populations such as patients who had impaired sensory function, different diseases or social economic backgrounds, and with different protective factors.
- (2) Designing a study that includes different predicting variables such as other indices for physiological stability, psychological stability, disease severity, and other medication dosage, to test the outcome variable.
- (3) Designing longitudinal research to understand the long-term consequences of cognitive disturbance on patients.
- (4) Identifying a shorter and more efficient tool for cognitive assessment in clinical settings.

Since research related to delirium and cognitive disturbance is a new area of study in Taiwan, it is necessary to develop a program of study. This program would start with qualitative research such as perception of nurses caring for the delirious patient, the patient's experience during a delirium episode, to quantitative research with correlational and causal research design to further understand the phenomena of delirium in the Taiwanese social context. Designing targeted intervention will be necessary to understand the effectiveness of the treatment. Collaborated research with other disciplines will foster the understanding of the complexity of delirium.

4.2. Strength and limitations

The secondary data analysis may limit the comprehensiveness of the theoretical model because of the limited selection of variables for study. Other variables, which are important to the post-surgical cognitive disturbance, cannot be included in this model including environmental factors and medication usage. The sample of this study was limited to subjects that were elderly with normal vision, hearing, and speech ability. The findings apply only to this specific population and limits generalization of the research findings to non-Chinese samples. Small sample size also limits the analysis of subgroups regarding different demographic characteristics of the sample.

The strength of the theoretical model is that there is a clear temporal order of the variables. One may question about how nurses had time to complete a battery of instruments with patients on busy surgical units. The selected variables in the model, which included cognitive function, physical function and some biochemistry and vital signs, can be easily assessed through simple tests or through medical records. It also represents features of everyday nursing practice. This assessment can be incorporated into routine nursing care and will increase the quality of nursing care.

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References

- American Psychiatric Association, 1994. Diagnostic and statistical manual of mental disorders, 4th Edition. American Psychiatric Association, Washington DC.
- Berggren, D., Gustavsson, Y., Eriksson, B., Bucht, G., Hansson, L.I., Reiz, S., Binblad, B., 1987. Postoperative confusion after anesthesia in elderly patients with femoral neck fractures. *Anesthesia Analogy* 66 (6), 497–504.
- Bruera, E., Franco, J., Maltoni, M., Watanabe, S., Suarez-Almazor, M., 1995. Changing pattern of agitated impaired mental status in patients with advanced cancer: association with cognitive monitoring, hydration and opioid rotation. *Journal of Pain and Symptom Management* 10 (4), 287–291.
- Cosgray, R., Davidhizar, R., Giger, J.N., Kreisl, R., 1993. A program for water-intoxicated patients at a state hospital. *Clinical Nurse Specialist* 7 (2), 55–61.
- Dai, Y.T., Lou, M.F., Yip, P.K., Huang, G.S., 2000. Risk factors and incidence of postoperative delirium in elderly Chinese patients. *Gerontology* 46 (1), 28–35.
- Davis, C., 1993. Laboratory values for the elderly. In: Carnevali, D.L., Patrick, M. (Eds.), *Nursing Management for the Elderly*, 3rd Edition.. Lippincott, Philadelphia, pp. 141–170.
- DeMaagd, G., 1995. High-risk drugs in the elderly population. *Geriatric Nursing* 16 (5), 198–207.
- Dolan, M.M., Hawkes, W.G., Zimmerman, S.I., Morrison, R.S., Gruber-Baldini, A.L., Hebel, R., Magaziner, J., 2000. Delirium on hospital admission in aged hip fracture patients: prediction on mortality and 2-year functional outcomes. *Journal of Gerontology: Medical Sciences* 55A (9), M527–M534.
- Duffy, M.E., Jacobsen, B.S., 2001. Univariate descriptive statistics. In: Munro, B.H. (Ed.), *Statistical Methods for Health Care Research*. Lippincott, Philadelphia, pp. 29–62.
- Dyer, C.B., Ashton, C.M., Teasdale, T.A., 1995. Postoperative delirium: a review of 80 primary data-collection studies. *Archives of Internal Medicine* 155 (5), 461–465.
- Elmstahl, S., Wahlfrid, C., Jerntrop, P., 1995. Precipitating and predisposing factors of acute confessional state among emergency department patients. *International Psychogeriatrics* 7 (4), 519–526.
- Espino, D.V., Jules-Bradley, A.C.A., Johnson, C.L., Mouton, C.P., 1998. Diagnostic approach to the confused elderly patient. *American Family Physician* 57 (6), 1358–1366.
- Folstein, M.F., Folstein, S.E., McHugh, P.R., 1975. Mini-mental state: a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research* 12 (3), 189–198.
- Foreman, J., Zane, D., 1996. Nursing strategies for acute confusion in elders. *American Journal of Nursing* 96 (4), 44–52.
- Foreman, M.D., Wakefield, B., Culp, K., Milisen, K., 2001. Delirium in elderly patients: an overview of the state of the science. *Journal of Gerontological Nursing* 27 (4), 12–20.
- Francis, J., 1992. Delirium in older patients. *Journal of American Geriatrics Society* 40 (8), 829–838.
- Francis, J., Martin, D., Kapoor, W.N., 1990. A perspective study of delirium in hospitalized elderly. *Journal of the American Medical Association* 363, 1097–1101.
- Fretwell, M.D., 1993. Aging changes in structure and function. In: Carnevali, D.L., Patrick, M. (Eds.), *Nursing Management for the Elderly*, 3rd Edition.. Lippincott, Philadelphia, pp. 130–170.
- Gomez, G., Gomex, E.A., 1989. Dementia? or delirium? *Geriatric Nursing* 10 (3), 141–142.
- Gustafson, Y., Berggren, D., Brannstrom, B., Bucht, G., Norberg, A., Hansson, L.I., Winblad, B., 1988. Acute confusional states in elderly patients treated for femoral neck fracture. *Journal of American Geriatrics Society* 36 (6), 525–530.
- Inouye, S.K., Charpentier, P.A., 1996. Precipitating factor for delirium in hospitalized elderly person: predictive model and interrelationship with baseline vulnerability. *Journal of the American Medical Association* 275, 852–857.
- Inouye, S.K., Viscoli, C.M., Horwitz, R.I., Hurst, L.D., Tinetti, M.E., 1993. A predictive model for delirium in hospitalized elderly medical patients based on admission characteristics. *Annals of Internal Medicine* 119, 474–481.

- Jacobson, S.A., 1997. Delirium in the elderly. *The Psychiatric Clinics of North America* 20 (1), 91–110.
- Jagmin, M.G., 1998. Postoperative mental status in elderly hip surgery patients. *Orthopaedic Nursing* 17 (6), 32–42.
- Katzman, R., Zhang, M., Qu, O.Y., 1988. A Chinese version of the mini-mental state examination: impact of illiteracy in a Shanghai dementia survey. *Journal of Clinical Epidemiology* 41, 971–978.
- Kline, R.B., 1998. *Principles and Practice of Structural Equation Modeling*. The Guilford Press, New York.
- Knight, M.M., 2000. Cognitive ability and functional status. *Journal of Advanced Nursing* 31 (6), 1459–1468.
- Koizumi, J., Shiraishi, H., Ofuku, K., Susuki, T., 1988. Duration of delirium shortened by the correction of electrolyte imbalance. *The Japanese Journal of Psychiatry and Neurology* 42 (1), 81–88.
- Levkoff, S.E., Cleary, P., Liptzin, B., Evans, D., 1991. Epidemiology of delirium: an overview of research issues and findings. *International Psychogeriatrics* 3, 149–169.
- Lipowski, Z.J., 1990. *Delirium: Acute Confusional States*. Oxford University Press, New York.
- Loewen, S.C., Anderson, B.A., 1988. Reliability of the modified motor assessment scale and the Barthel index. *Physical Therapy* 68 (7), 1077–1081.
- Mach, J.R., Dysken, M.W., Kuskowski, M., Richelson, E., Holden, L., Jilk, K.M., 1995. Serum anticholinergic activity in hospitalized older persons with delirium: a preliminary study. *Journal of American Geriatrics Society* 43 (5), 491–495.
- Mahoney, F.I., Barthel, D.W., 1965. Functional evaluation: the Barthel index. *Maryland State Medical Journal* 14 (2), 61–65.
- Marcantonio, E.R., Goldman, L., Mangione, C.M., Ludwig, L.E., Muraca, B., Haslauer, C.M., 1994. A clinical prediction rule for delirium after elective non-cardiac surgery. *Journal of the American Medical Association* 271 (2), 134–139.
- Marcantonio, E.R., Flacker, J.M., Michaels, M., Resnick, N.M., 2000. Delirium is independency associated with poor functional recovery after hip fracture. *Journal of American Geriatrics Society* 48 (6), 618–624.
- Martin, N.J., Stones, M.J., Young, J.E., Bedard, M., 2000. Development of delirium: a prospective cohort study in a community hospital. *International Psychogeriatrics* 12 (1), 117–127.
- Mast van der, R.C., 1996. Delirium: the underlying pathophysiological mechanisms and the need for clinical research. *Journal of Psychosomatic Research* 41 (2), 109–113.
- McDougall, G., 1995. A critical review of research on cognitive function/impairment in older adults. *Archives of Psychiatric Nursing* 4 (1), 22–33.
- Mentes, J., Culp, K., Maas, M., Rantz, M., 1999. Acute confusion indicators: risk factors and prevalence using MDS data. *Research in Nursing & Health* 22 (1), 95–105.
- Milisen, K., Abraham, I.L., Broos, P.L.O., 1998. Postoperative variation in neurocognitive and functional status in elderly hip fracture patients. *Journal of Advanced Nursing* 27 (1), 59–67.
- Miller, P.S., Richardson, J.S., Jyu, C.A., Lemay, J.S., Hiscock, M., Keegan, D.L., 1988. Association of low serum anticholinergic activity levels and cognitive impairment in elderly presurgical patients. *American Journal of Psychiatry* 145 (3), 342–345.
- O'Keeffe, S., Lavan, J., 1997. The prognostic significance of delirium in older hospital patients. *Journal of American Geriatrics Society* 45 (2), 174–178.
- Parente, R., Herrmann, D., 1996. *Retraining Cognition: Techniques and Application*. Aspen, Maryland.
- Patrick, M., 1993. Characteristics of older people and introduction to theories of aging. In: Carnevali, D.L., Patrick, M. (Eds.), *Nursing Management for the Elderly*, 3rd Edition.. Lippincott, Philadelphia, pp. 87–98.
- Pompei, P., Foreman, M., Rudberg, M.A., Inouye, S.K., Braund, V., Casse, C.K., 1994. Delirium in hospitalized older persons: outcomes and predictors. *Journal of American Geriatrics Society* 42 (8), 809–815.
- Resnick, B., Daly, M.P., 1998. Predictors of functional ability in geriatric rehabilitation patients. *Rehabilitation Nursing* 23 (1), 21–29.
- Richards, S.H., Peters, T.J., Coast, J., Gunnell, D.J., 2000. Inter-rater reliability of the Barthel ADL index: how does a researcher compare to a nurse? *Clinical Rehabilitation* 14 (1), 72–78.
- Ritchie, K., Polge, C., Roquefeuil, G., Djakovic, M., Ledesert, B., 1997. Impact of anesthesia on the cognitive functioning of the elderly. *International Psychogeriatrics* 9 (3), 309–326.
- Robert, B.L., Lincoln, R.E., 1988. Cognitive disturbance in hospitalized and institutionalized elders. *Research in Nursing & Health* 37, 150–154.
- Royall, D.R., Chiodo, L.K., Polk, M.J., 2000. Correlates of disability among elderly retirees with “subclinical” cognitive impairment. *Journal of Gerontology: Medical Science* 55A (9), M541–M546.
- Rudberg, M.A., Pompei, P., Foreman, M.D., Ross, R.E., Cassel, C.K., 1997. The natural history of delirium in older hospitalized patients: a syndrome of heterogeneity. *Age and Ageing* 26, 169–174.
- Schor, J.D., Levkoff, S.E., Lipsitz, L.A., 1992. Risk factors for delirium in hospitalized elderly. *Journal of the American Medical Association* 267, 827–831.
- Smita, S., Parika, M.D., Chung, F., 1995. Postoperative delirium in the elderly. *Anesthesia Analogy* 80, 1223–1232.
- Stromberg, L., Lindgren, U., Nordin, C., Ohlen, G., Svensson, O., 1997. The appearance and disappearance of cognitive impairment in elderly patients during treatment for hip fracture. *Scandinavian Journal of Caring Sciences* 11 (3), 167–175.
- Tabachnick, G.B., Fidell, L.S., 1996. *Using Multivariate Statistics*, 3rd Edition.. Harper Collins College Publishers, New York.
- Tombaugh, T.N., McIntyre, N.J., 1992. The mini-mental state examination: a comprehensive review. *Journal of American Geriatrics Society* 40 (9), 922–935.
- Tune, L.E., 1991. Postoperative delirium. *International Psychogeriatrics* 3 (2), 325–332.
- Tune, L., Carr, S., Cooper, T., Klug, B., Golinger, R.C., 1993. Association of anticholinergic activity of prescribed medications with postoperative delirium. *Journal of Neuro-psychiatry and Clinical Neuroscience* 5 (2), 208–210.

- Wade, D.T., Collin, C., 1988. The Barthel ADL index: a standard measure of physical disability. *International Disability Studies* 10 (2), 64–67.
- Williams, M.A., Campbell, E.B., Raynor, W.J., Musholt, M.A., Mlynarczyk, S.M., Crane, L.F., 1985. Predictors of acute confusional states in hospitalized elderly patients. *Research in Nursing & Health* 8 (1), 31–40.
- Williams-Russo, P., Urquhart, B.L., Sharrock, N.E., Charlson, M.E., 1992. Post-operative delirium: predictors and prognosis in elderly orthopedic patients. *Journal of the American Geriatrics Society* 40 (8), 759–769.
- Williams-Russo, P., Sharrock, N.E., Mattis, S., Szatrowski, T.P., Charlson, M.E., 1995. Cognitive effects after epidural vs. general anesthesia in older adults: a randomized trial. *Journal of the American Medical Association* 274 (1), 44–50.
- Zelinski, E.M., Crimmins, E., Reynolds, S., Seeman, T., 1998. Do medical conditions affect cognitive in older adults? *Health Psychology* 17 (6), 504–512.