

Nurse-led sedation for transfemoral transcatheter aortic valve implantation seems safe for a selected patient population

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Transcatheter aortic valve implantation (TAVI) has become a high-volume procedure with increasing demands on hospital resources. Local anaesthesia with sedation supervised by an anaesthesiology team is the current standard of care. We aimed to describe our experience with a simplified, nurse-led sedation (NLS) protocol. This study enrolled 128 consecutive patients who underwent transfemoral TAVI with self-expandable Evolut R prosthesis between November 2019 and April 2021. Operators selected 50% of patients for NLS based on the clinical expectation of lower risk of procedural difficulties. Nurse-led sedation protocol demanded only mild to moderate levels of sedation. The clinical outcomes were determined from the local TAVI registry and the national mortality database. Baseline patient characteristics were similar in the NLS ($n=64$) and anaesthesiologist-led sedation (ALS) ($n=64$) groups except higher prevalence of diabetes mellitus (48.4% vs. 31.3%, $P=0.035$) and peripheral vascular disease (20.3% vs. 7.8%, $P=0.036$) in the ALS group. There was a trend for the larger prostheses used in the ALS group ($P=0.058$). The procedural results did not differ, and coronary care team backup was rarely needed in the NLS group (6% of patients). The in-hospital outcomes were identical from both clinical and echocardiography perspectives, and 30-day mortality was low in both groups (1.5%). For the NLS group, preparation in the catheterization laboratory was quicker by 6.4 min ($P=0.01$), and intensive care unit stay was shorter (2.03 vs. 3.48 days, $P=0.001$). In conclusion, the NLS for the selected transfemoral TAVI population seems safe.

Introduction

Transcatheter aortic valve implantation (TAVI) is an established treatment for severe aortic stenosis with excellent results. With growing experience, many groups have

developed protocols with pre-procedural, peri-operative, and post-procedural pathways aimed at TAVI simplification. Many centres have safely replaced general anaesthesia for TAVI with local anaesthesia with sedation (administered by a qualified anaesthesiologist).^{1,2} Fully percutaneous approach with the use of vascular closure devices has become routine for the transfemoral access route.³ Pre-implantation aortic valve balloon valvuloplasty use seems

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to decline with operators' experience and is no longer mandatory for all cases.^{4,5} Left ventricle over-the-wire stimulation during TAVI was associated with significantly reduced procedure duration, fluoroscopy time, and cost, with similar efficacy and safety.⁶ The transradial secondary approach to guide the prosthesis implantation might be a safer alternative to the transfemoral secondary approach.⁷ The first reports of nurse-led sedation (NLS) for transfemoral TAVI have been reported.⁸⁻¹¹ This has the potential to further optimize the hospital resources and streamline TAVI service.

We aimed to describe our NLS protocol and compare clinical results and patient safety in NLS and anaesthesiologist-led sedation (ALS) groups.

Methods

Study population

This prospective, academic, single-centre study included all consecutive patients who underwent transfemoral TAVI in University Hospital Královské Vinohrady, Prague, between 1 November 2019 and 30 April 2021. All included patients provided written informed consent; data were prospectively entered into a dedicated anonymized database. The study was funded by the Intercardis project. The study protocol complied with the Declaration of Helsinki and was approved by the local Ethical Committee. The study was designed and started before the onset of the coronavirus disease-19 (COVID-19) pandemic. The patient eligibility for the nurse-supported TAVI approach was determined at weekly cardiology TAVI-team meetings. There was a 50:50% ratio of TAVI slots allotted to anaesthesiologist-supported and nurse-supported procedures. There were no strict pre-specified criteria for patient selection. Multifactorial clinical evaluation included: peripheral vascular disease of transfemoral access route, obesity, poor cooperation, large prosthesis size, horizontal aorta, and chronic pulmonary disease. In principle, the experienced TAVI operator selected 50% of patients with expected lower risk of complications and technical difficulties during TAVI for the nurse-led procedure at the weekly TAVI-team meeting. The procedural and in-hospital outcome was determined from the hospital TAVI registry and 30-day mortality was extracted from the national mortality database.

Transcatheter aortic valve implantation and sedation technique

Two interventional cardiologists performed all implantations in a regular cardiac catheterization laboratory with routine use of fluoroscopy and computed tomography fusion imaging. All patients had peri-procedural continuous arterial pressure monitoring using the side-arm of secondary access arterial sheath with the preference of the right radial route. Central venous access was provided from the femoral vein. Oxygen saturation was monitored by finger pulse oximetry. The level of consciousness was assessed by the Ramsay sedation scale (RSS) every 5 min.¹² Large-bore arterial access was gained from a more favourable femoral artery under ultrasound guidance; ultrasound also enabled

the precise application of local anaesthesia using 20 ml of 1:1 mixture of trimecaine and longer-acting bupivacaine. The decisions regarding the need for balloon aortic valve pre-dilatation and the mode of pacing (via 5-Fr balloon-tipped electrode in the right ventricle or over the stiff wire in the left ventricle) were up to the operators. Evolut R self-expandable transcatheter prosthesis (Medtronic, Minneapolis, MN, USA) was used in all patients. The right and left cusp overlap fluoroscopic view was derived from the computed tomography dataset and used for the implantation.¹³ Aortography and haemodynamic measurement were used to evaluate the severity of aortic regurgitation at the end of the procedure. Percutaneous suture-based closure of transfemoral access point was the primary approach, and the absence of bleeding was confirmed by angiography in all cases.

The anaesthesiology team consisted of a qualified anaesthesiologist and a nurse and routinely used the continuous infusion of propofol, and remifentanyl titrated to the desired effect. A dedicated team of catheterization laboratory nurses was trained in sedation by the expert anaesthesiologist (M.S. and F.B.). The nurse administering sedation during TAVI concentrated fully on the patient assessment and was not assigned any other responsibilities during the case. A combination of midazolam 1 mg IV and ketamine 25 mg IV bolus was used for NLS and repeated if required. Paracetamol 1 g infusion or fentanyl 0.025 mg bolus IV could be administered for pain relief. Flumazenil, naloxone, and inotropes were readily available. Per hospital protocol for non-anaesthesiologist-supported sedation, only a mild to moderate level of sedation (RSS 1 to 4) was achieved. In case of an emergency, during the procedure, the coronary care unit physician was called on a dedicated phone number and was available within minutes. All clinical variables were defined per Valve Academic Research Consortium 3 (VARC-3) criteria.¹⁴

Statistical analysis

Continuous variables are presented in graphs and tables as means and standard deviations. Categorical variables are reported as counts and frequencies. Continuous variables were compared between groups using the Student's *t*-test or Mann-Whitney *U* test. Categorical variables were compared between groups using the chi-squared test or Fisher's exact test. *P*-values <0.05 were considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics, version 26. Graphical analyses were performed using Sigma Plot, version 14.

Results

Our study included 128 consecutive transfemoral TAVI patients, 64 in the NLS group and 64 in the ALS group (Table 1). There were no statistically significant differences in baseline patient characteristics except for the following: patients in the ALS group had higher prevalence of diabetes mellitus (48.4% vs. 31.3%, *P*=0.035) and peripheral vascular disease (20.3% vs. 7.8%, *P*=0.036). The echocardiography-derived parameters of left ventricular

Table 1 Baseline patient characteristics

	NLS (n = 64)	ALS (n = 64)	P-value
Male gender	32 (50.0%)	36 (56.3%)	0.566
Height (cm)	166.8 ± 9.1	169.3 ± 8.4	0.113
Weight (kg)	78.4 ± 14.0	85.3 ± 20.0	0.231
EuroScore I logistical (%)	10.3 ± 6.9	12.2 ± 11.9	0.886
EuroScore II (%)	4.6 ± 4.1	5.7 ± 6.7	0.684
Smoking (past or current)	27 (42.2%)	31 (48.4%)	0.580
Dyspnoea NYHA III + IV	37 (57.8%)	44 (68.8%)	0.463
Diabetes Mellitus	20 (31.3%)	31 (48.4%)	0.035
Hypertension	55 (85.9%)	52 (81.3%)	0.317
Chronic obstructive pulmonary disease	7 (10.9%)	9 (14.1%)	0.395
Previous myocardial infarction	12 (18.8%)	9 (14.1%)	0.317
Previous stroke/TIA	6 (9.4%)	9 (14.1%)	0.292
Previous coronary artery bypass grafting	7 (10.9%)	11 (17.2%)	0.223
Previous atrial fibrillation	30 (46.9%)	23 (35.9%)	0.141
Previous percutaneous coronary intervention	24 (37.5%)	23 (35.9%)	0.500
Syncope	12 (18.8%)	14 (21.9%)	0.413
Peripheral vascular disease	5 (7.8%)	13 (20.3%)	0.036
Pacemaker before TAVI	9 (14.1%)	11 (17.2%)	0.404
Left ventricular ejection fraction	55.63 ± 12.6	52.7 ± 14.1	0.175
Mean aortic valve gradient (mmHg)	43.2 ± 17.6	44.9 ± 19.5	0.605
Aortic valve area (cm ²)	0.9 ± 0.2	0.9 ± 0.3	0.319

Values are n (%) or mean ± SD.

ALS, anaesthesiologist-led sedation; NLS, nurse-led sedation; NYHA, New York Heart Association; TAVI, transcatheter aortic valve implantation; TIA, transient ischaemic attack.

ejection fraction and severity of aortic stenosis were similar in both groups.

Procedural details are summarized in *Table 2*. There was a clear trend for the large 34 mm Evolut R prosthesis being used more often in the ALS group (35.9% vs. 15.6%, $P=0.058$). Secondary arterial access from the right radial artery was preferred in both groups. Aortic valve pre-dilatation was performed in only 10.9% of cases in both groups. The rate of prosthesis post-dilatation was low and similar in both groups (6.3% vs. 9.4% in the ALS vs. NLS groups, $P=0.37$). The angiographically graded paravalvular regurgitation at the end of the procedure was similar in both groups with the cumulative rate of moderate or severe regurgitation around 12% in both groups. The patient preparation time (entry into the laboratory to first vascular puncture) was shorter in the NLS group (39.3 vs. 45.7 min, $P=0.01$). The implantation time (first vascular puncture to all catheters extraction) did not differ between groups. The radiation dose, fluoroscopy time, and amount of contrast agent were similar in both groups. The coronary care physician back-up was required in four cases (2 × hypotension, 1 × poor cooperation, 1 × complete heart block) and no patient in the NLS group required intubation. Technical success at the exit from the catheterization laboratory (per VARC-3 criteria) was achieved in all patients in both groups.

In-hospital complications are summarized in *Figure 1*. Overt bleeding (type 1–4 per VARC-3 criteria) was present in six patients in the NLS group and seven patients in the

ALS group ($P=0.42$) and was in all cases access-site related. Stroke was a rare complication in both groups. The rate of new permanent pacemaker implantation was similar and under 10% in both groups. The haemodynamic performance of transcatheter prosthesis on pre-discharge transthoracic echocardiography was excellent in both groups—mean aortic valve area 1.95 vs. 2.25 cm² ($P=0.25$); moderate or severe paravalvular regurgitation in 7 vs. 9 patients ($P=0.34$) for NLS vs. ALS groups. Independent mortality analysis from the national database at 30 days post-TAVI revealed one deceased patient in both groups, both patients suffered from a peri-TAVI stroke. The intensive-care unit stay was significantly shorter in the NLS group (2.03 vs. 3.48 days, $P=0.001$). Also, a simple cost analysis revealed ~1.500 USD saved per patient in the NLS group.

Discussion

This study compares NLS with the standard ALS protocol in patients undergoing transfemoral TAVI with modern self-expandable prosthesis. The main findings of this study are the following: (i) expected procedural difficulties due to peripheral vascular disease or a large prosthesis size appear to be significant factors in sedation mode selection by the operator; (ii) clinical results and complications are similar with or without the presence of anaesthesiologist in the room; and (iii) the NLS might result in shorter intensive care stay and cost savings.

Table 2 Procedural details

	NLS (n = 64)	ALS (n = 64)	P-value
Evolut R prosthesis size (mm)			
23	3 (4.7%)	2 (3.1%)	0.058
26	21 (32.8%)	13 (20.3%)	
29	30 (46.9%)	26 (40.6%)	
34	10 (15.6%)	23 (35.9%)	
Secondary access site			
Radial artery	42 (65.6%)	36 (56.3%)	0.183
Femoral artery	22 (34.4%)	28 (43.8%)	
Aortic valve pre-dilatation	7 (10.9%)	7 (10.9%)	0.611
Aortic valve post-dilatation	6 (9.4%)	4 (6.3%)	0.372
Aortic regurgitation			
None/mild	56 (87.5%)	57 (89.1%)	0.098
Moderate	8 (12.5%)	5 (7.8%)	
Severe	0 (0.0%)	2 (3.1%)	
Preparation time (min)	39.33 ± 10.49	45.67 ± 15.98	0.011
Implantation time (min)	82.69 ± 24.42	85.26 ± 31.04	0.962
Contrast volume (mL)	123.9 ± 51.7	134.1 ± 48.9	0.299
Fluoroscopy time (min)	16.5 ± 7.9	17.1 ± 8.3	0.630
Radiation dose (Gy.cm2)	43.9 ± 31.5	50.4 ± 40.3	0.613

Values are n (%) or mean ± SD.

ALS, anaesthesiologist-led sedation; NLS, nurse-led sedation.

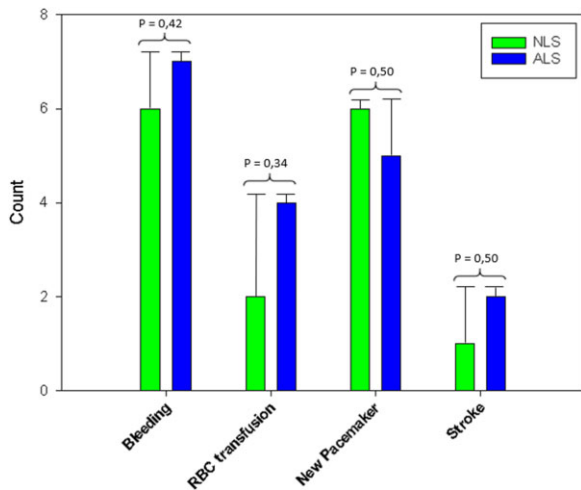


Figure 1 Comparison of in-hospital complications between the nurse-led sedation and anaesthesiologist-led sedation protocols.

The process of TAVI simplification resembles the development of percutaneous coronary interventions from a simple lesion intervention with anaesthesia supervision and cardiac surgery back-up to the current practice where complex coronary lesions are commonly approached by a single operator with expert nursing team support. This process is enabled by larger experience with percutaneous aortic valve interventions and at the same time driven by increasing TAVI volume which makes the anaesthesia availability and cost of care an important issue. Three groups have reported the feasibility of local anaesthesia with no or mild sedation even with the first generation TAVI prostheses.¹⁵⁻¹⁷ In the more contemporary practice, Konigstein

*et al.*⁸ compared the local anaesthesia and sedation approach administered by anaesthesiologist or cardiologist in mostly intermediate-risk TAVI patients in different periods. Transcatheter prostheses were different, but otherwise, no baseline differences were apparent and the presence of an anaesthesiologist had no impact on the 30-day clinical outcome. Sathanathan *et al.*¹⁰ published a subanalysis of Vancouver 3M TAVR study regarding local anaesthesia only (i.e. no sedation) with no impact on procedural variables or early outcomes. Vendrik *et al.*⁹ reported on the nurse-led analgesia protocol for transfemoral TAVI amidst a global COVID-19 crisis. The published selection criteria resulted in a selection of approximately one-third of consecutive TAVI patients for the nurse-led analgesia and this strategy seemed feasible and safe. Interestingly, the selection criteria included among others the large prosthesis size and difficult femoral access in agreement with our experience. Keegan *et al.*¹¹ used the propensity matching to compare NLS with moderate sedation by the anaesthesiology team and concluded that procedure-room time was shorter with similar clinical outcomes. There is large variability in intravenous sedation medication protocols between the above studies. The major difference does not seem to be the specific properties of any drug but rather the level of sedation. We feel that the ultrasound-guided cannulation of the common femoral artery for the large-bore TAVI arterial access might be an important procedural aspect. In our experience, this approach enables more precise local anaesthesia and might reduce pain and improve patients' comfort, as previously reported.¹⁸ There are several gaps in available evidence: no randomized studies of NLS were published, patient experience related to different levels of sedation is

not known and no formal cost-effectivity analysis has been reported.

Our study has several limitations. A non-randomized study was performed at a single experienced centre and results may not be applicable to lower volume centres. The selection process for NLS was real-life and practical, but not precisely defined and rather based on clinical judgement and this may introduce confounding bias.

In conclusion, the practice of NLS for transfemoral TAVI in a patient population with a low expected risk of complications is feasible and safe. Procedural and clinical results are similar to standard anaesthesia-supported care. Potential benefits of nurse-led mild sedation might be shorter post-procedure intensive care and lower cost. Further research is warranted including randomization, patient perception, and formal cost-effectivity analysis.

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Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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