Original Article

Factors Influencing Challenging Colonoscopies During Anesthesiologist-Assisted Deep Sedation

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ABSTRACT

Background/Aim: Increased demand for colon cancer screening procedures can significantly impact on routine colonoscopy management at dedicated facilities, prompting a review of the factors that can negatively affect workflow. Although potential adverse effects and impact on costs of deep sedation have been documented elsewhere, this study focuses on variables that can influence performance of colonoscopy in deep sedation and interfere with normal procedure scheduling in settings where the presence of an anesthesiologist is mandatory. **Patients and Methods:** We performed a cross-sectional study of the activities of a colonoscopy screening unit, applying Bayesian Network (BN) analysis, designed to assess interdependencies among variables that can affect a process in complex, multidimensional systems. The study was performed at a teaching hospital where endoscopists and anesthesiologists of varying work experience operate on a rota basis. During a six-month period, we analyzed 1485 consecutive colonoscopies performed under deep propofol sedation, administered by an anesthesiologist via hand-controlled syringe. The BN was constructed with the variables: Gender, age, ASA status, bowel preparation, baseline blood pressure, endoscopist's experience, anesthesiologist's experience, presence of polypectomy, and the target node, "challenging procedure." This previously undefined category refers to any events disrupting the scheduled rota. **Result and Conclusion:** Two distinct networks were identified. One deals mainly with relationships among the variables, patients' demographic and clinical characteristics (procedures with polypectomy, ASA and baseline blood pressure). The other explains relationships among the variables, "challenging procedure," bowel preparation, and endoscopist's experience. The factors associated with the anesthesiologist's activity do not influence challenging colonoscopies.

Key Words: Bayesian network, colon cancer screening, colonoscopy, deep sedation colonoscopy

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Colon cancer screening activities shed light on the organizational aspects of endoscopy units, which must cater for increased demand for colonoscopies while ensuring successful clinical outcomes and patient satisfaction.[1,2] Because workflow management, staff commitment, and procedure costs underpin endoscopy facility efficiency,[3] the introduction of deep sedation into the setting has produced a series of variables that deserve closer investigation. Deep sedation boosts patient acceptance, thereby improving the success rate.[4] It can also impede technical performance, as making it difficult to change the position of the sedated patient to facilitate smooth endoscope passage or to better visualize parts of the colon.[5] When used inappropriately, it can result in oversedation.[6] Additionally, in the majority of endoscopy centers the use of propofol requires the presence of another health professional working in tandem with the endoscopist.[7] This jeopardises the use of deep sedation in many countries. In Italy, for example, propofol must be administered by an anesthesiologist, in accordance with regulations on the use of anesthetics. To date, the disadvantages of this situation have been considered chiefly in economic terms. Results have shown that the presence of an anesthesiologist may raise the cost of the procedure by up to 285%[8] and increase organizational complexity, without necessarily improving service quality, as demonstrated in other settings.[9] It is not yet clear whether the presence of anesthesiologist affects the technical aspects of colonoscopy, which ought to depend solely on the skill and practical experience of endoscopist.

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To investigate these issues, we examined the factors that can affect the efficiency of colonoscopy in the propofol era and determine a challenging procedure. To assess the complex interrelationships in this setting we used the Bayesian Network (BN) approach, instead of the variance analysis usually applied to similar studies. Bayesian Network is a statistical model that recognizes most real domains are complex, multidimensional systems and that the main goal of applied research is to establish which variables define systems and their interrelationships. BN is a representation of knowledge that can capture this information. Briefly, BN is a concise representation of a joint probability distribution whose graphical probabilistic model consists of a qualitative part (structure) specifying the conditional in/dependencies among the variables, and a quantitative part specifying the conditional probabilities of the dataset variables (parameters). Formally, the BN is a directed acyclic graph (DAG) where each node represents a random variable, the edges represent relationships, and the target node represents the outcome variable.

We used the BN to analyze routine screening colonoscopy practice at a teaching hospital with the added analytical advantage of having numerous anesthesiologists and endoscopists, of varying backgrounds and experience, working on a rota basis.

MATERIALS AND METHODS

We conducted a cross-sectional study to review the endoscopy reports and anesthesia records of colonoscopies consecutively performed under deep propofol sedation at Padova University teaching hospital, over a period of six months. The final sample constituted 1485 colonoscopies. We assessed variables influencing anesthesiological risk (age, American Society of Anaesthesiologists [ASA] score, other comorbidities), procedure completeness (cecal intubation or diagnosis of impassable stenosis), performance of polypectomies, and colon preparation.

The endoscopists and anesthesiologists were classified according to experience (more or less than 10 years' experience for endoscopists, and by number of years in practice, that is, 2, 5, or over 5 years in the case of anesthesiologists). Endoscopists with over 10 years' experience were also classified by their prevalent area of practice, as defined elsewhere,[10] and by calculating the number of sessions handled per week (more or less than four).

The propofol dose administered during patient sedation was left to the complete discretion of the anesthesiologist, based on estimated anesthesiological risk and maintenance of optimal patient relaxation.

Because the primary objective of the study was to analyze the variables that can interfere with the routine work schedule, we created the "challenging procedure" category. Besides incomplete procedures, the category included colonoscopies with anesthesiological or technical adverse events,[11] or with a dose of propofol/kg one standard deviation above the mean, or lasting one standard deviation in minutes above the mean. Procedures can become challenging and affect overall endoscopy unit workload because excess dose or longer duration can increase the need for additional maneuvers to maintain vital parameters.

To avoid the Hawthorne effect, endoscopists and anesthesiologists were blind to the study.

Statistical analysis used

Bayesian network

The BN was constructed using Hugin Researcher 6.9 software ([Online] available at www.hugin.com). The BN is a method for representing probabilistic relationships between variables associated with an outcome of interest. Formally, a BN is a pair (G, Θ) where G is the Directed Acyclic Graph (DAG), consisting of nodes and edges, and $\Theta = (\theta_{x1},\ldots, \theta_{xn})$ is a set of parameter values that specify all the conditional probability distributions. The nodes are in one-to-one correspondence with the random variables $\{X_1,\ldots, X_n\}$, whereas the edges indicate direct dependencies between the variables. The graph G encodes in/dependence relationships of the domain, which can be read from G by means of the d-separation criterion.[12] Each conditional probability distribution has the form $\theta_{xi/Paxi} = P\ (x_i/\mathrm{Pa}_{xi})$ for each value x_i of X_i; and Pa_{xi} of Pa_{Xi} where Pa_{Xi} denotes the set of direct parents of X_i in G (the nodes pointing to X_i in the graph). The joint probability distribution $P\ (\mathbf{X})$ and G are connected by the Markov Condition property:[13] Each node is conditionally independent of its nondescendant, given its parents, and $P\ (\mathbf{X})$ is expressed through the factorization: $P(\mathbf{X}) = \Pi_I\ P\ (X_i)/Pa_{Xi}) = \Pi_i\ \theta_{Xi/\mathrm{PaX}i}$.

The independence of the variables is easy to recognise (the absence of arcs means there is a conditional independence relationship), whereas conditional relationships are defined by a directed graph edge. After its construction, the BN must be validated. With a high dimension dataset, the most common and correct approach is to divide the data into subsets by inference. The data are usually divided into two subsets: a training set (containing 75% of the data) and a validation or test set (containing the remaining 25%). The training set is used to construct the model, whereas the test set is used to estimate and validate the resulting model. This approach is known as cross-validation. Moreover, we focus on BN structures, under the restriction of complete data, that is, without missing cases.

Ethical considerations

The study was not conducted for profit and all patients were asked to give their informed consent to the procedure and to the processing of their personal details. According to Italian Drug Agency (AIFA) guidelines, observational studies using retrospective data or materials do not require formal approval by the local Ethics Committee.

RESULTS

During the six-month study period, 1485 colonoscopies were performed by 14 endoscopists and 42 anesthesiologists during the routine weekly work schedule. The mean administered dose of propofol was 189.2 ± 79.3 mg (range 20–650 mg), with a mean of 2.73 mg/kg (range 0.24–9.83). Of the procedures, 46.8% were for males, with a statistically significantly higher mean age (61.7 ± 13.3 years) than the females (60.1 ± 14.3). Among the patients, 561 (37.8%) had an ASA score of I, 794 (53.5%) scored II and 130 (8.7%) had scores of III and IV. In 41% of the patients, baseline systolic pressure was ≥90 and ≤140 and/or the diastolic reading was ≤80.

Five endoscopists had less than 10 years of experience and performed 11% of the colonoscopies. Six of those with over 10 years of experience performed less than four sessions per week, carrying out 65% of the procedures. The remaining 23% of the colonoscopies were performed by three dedicated endoscopists with more than 10 years of service, who handled at least four endoscopy sessions per week.

The 24 anesthesiologists with least experience administered deep sedation in 79.2% of cases. Thirteen with more than two years of experience were involved in 16.5% of the colonoscopies. The 13 who had just completed their residency practiced sedation in 4.3% of procedures.

A total of 1377 colonoscopies were completed (92.7%). The mean duration of the procedure was 25 min (SD ± 12.6, range 4–95). Preparation was considered adequate in 71% of procedures, and some residual matter was present in 24.1%, preventing completion in 4.9% of them. Polypectomy was performed in 17% of colonoscopies.

Based on the selected characteristics, a total of 332 procedures were considered "challenging." The variables used to construct the BN were gender, age, ASA status, bowel preparation, baseline blood pressure, endoscopist's experience, anesthesiologist's experience, presence of polypectomy, and the target node, "challenging procedure." The resulting BN is shown in Figure 1.

Two distinct networks were identified; one dealing mainly with patients' demographic–clinical characteristics and the other explaining the relationships among a "challenging procedure," bowel preparation and the endoscopist's experience. The variable explaining the anesthesiologist's experience proved to be irrelevant to the BN.

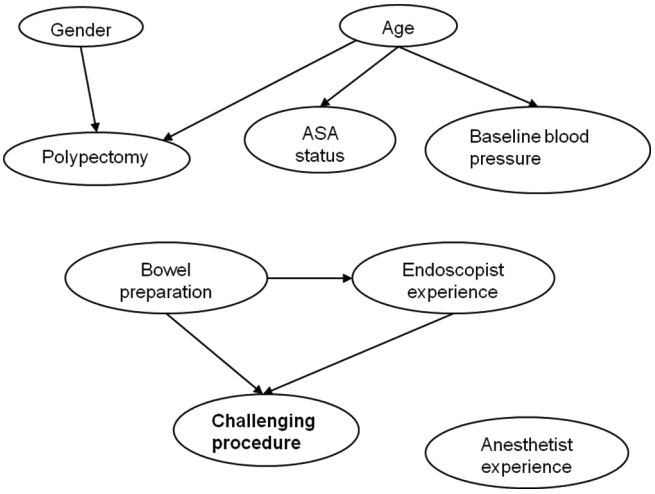

Figure 1: Bayesian network

In the first BN, the clinical characteristics (polypectomy, ASA, and baseline blood pressure) were directly dependent on the age of patient, whereas polypectomy was also dependent on gender. In the second BN, the Markov blanket of the "challenging procedure" consisted of the variables "bowel preparation" and "endoscopist's experience" (the children), indicating that if the adequacy of bowel cleanliness and endoscopist's experience level are known, no other variable is needed to provide further information on the "challenging procedure."

Performing inference with a BN means computing the conditional probability for some variables based on information (evidence) available on other variables. The target node for our analysis was "challenging procedure." The estimated posterior probabilities, calculated with Hugin Researcher 6.9 software, ranged from 4% (15 subjects) to 52% (8 subjects), and each probability level was associated with a response combination in the dataset. Table 1 shows the patient characteristics associated with a low (14%, $n = 61$) posterior probability of having a "challenging procedure," that is, adequate bowel preparation (100%), being female (55.7%), younger age (31.2%), an ASA score of II (52.5%), and no polypectomy (83.6%).

DISCUSSION

Weinstein *et al.* intriguingly referred to propofol as the "white elephant in the room," because its administration can alter the complex relationship existing among process quality, safety, and costs.[14] Using a BN for the first time to model the determinants of a challenging colonoscopy, our study revealed a conditional independence relationship

Table 1: Main characteristics (%) of patients with low posterior probability (14%) of having a "challenging procedure"

Posterior probability (%)	Gender		Age (year)			
	Male	Female	14-52	53-63	64-71	72-95
14	44.3	55.7	31.2	29.5	22.9	16.4

	Polypectomy	ASA score			Bowel preparation			Baseline blood pressure
	No	1	2	3+4	Adequate	With residual matter	Inadequate	90≤ systolic ≤140 and diastolic ≤80
14	83.6	42.6	52.5	4.9	100	-	-	37.7

ASA: American society of anesthesiologists

between patients' demographic/clinical characteristics and the colonoscopy procedure (absence of arcs). According to the Markov property (ie, that each node is conditionally independent of all others, given its Markov blanket), two variables only—bowel preparation and endoscopist experience—are needed to describe the probability of a challenging procedure.

We were keen to investigate whether endoscopists are gradually losing their central role in the colonoscopy room due to changes in colonoscopy practice, with the introduction of patient sedation practices, patient monitoring methods, and new tools. Interestingly, the BN confirms the two key critical areas hypothesized by Inadomi[15] (one patient- and one procedure-related), that is, bowel preparation and endoscopist's experience.

The relationships between age, gender, presence of polyps, and ASA status confirm established physiological factors[16] and demonstrate the validity of the adopted statistical model. Moreover, the probability of determining groups by procedure complexity among our patients shows that age over 72 years with comorbidities and an ASA score of over II are important characteristics, consistent with previous observations.[17-18] Surprisingly, the majority of patients with a nonchallenging procedure were women, whereas other studies have reported that while the time taken to reach the cecum is longer in women, there is no difference between men and women in overall procedure time.[19]

It could be argued that the introduction of the "challenging procedure" category to the classical category of complete procedures or procedures with adverse events, is a weakness of the study, considering that the endoscopy unit had above average performance times and propofol doses. The significance of procedure duration varies; in the introductory phase it depends on technical characteristics but becomes a measure of accuracy in the withdrawal phase. The mean performance time (25 min) was higher in our survey than in previous studies[11] and is probably related to sedation practices. Longer-than-average duration has been considered a determinant of procedure difficulty because there is an association between the duration of procedures performed under sedation and the risk of hypoxia.[20] The higher dose of propofol administered to patients in our study as compared with others[21] is undoubtedly a determining factor in this respect, probably because it was left to the complete discretion of the attending anesthesiologists, who tended to administer higher doses of propofol, as demonstrated elsewhere. Considering the variability of individual patient response,[22] this can frequently induce episodes of hypoxia as compared with dose administration based on standard procedures.[23]

One of the objectives of our study was to determine the influence of anesthesiologist on colonoscopic performance. Errors in the assessment of patient comfort and safety related to inexperience can lead to imprecision in propofol dosing. The importance of experience in the colonoscopy setting has been demonstrated by a survey comparing endoscopist- versus anesthesiologist-administered propofol.[24] In agreement with our findings, other reports have shown that the administration of sedatives during the procedure is related more to endoscopist performance than to patient age or ASA score.[25] We assumed that giving a professional other than endoscopist complete discretion over the hand-controlled syringe could influence the procedure. It would have been more informative to conduct a controlled study with administration of deep sedation to one group by a nonanesthesiologist. However, medical and legal constraints on the administration of anesthetics in Italy prevent us from conducting this type of investigation.

By demonstrating that the anesthesiologist's experience and "sedation package" are not determinants of procedure-related adverse events, we believe that the Bayesian model provides further evidence in favor of more simplified propofol management during colonoscopy in young patients with low ASA status.

Prior to our study, the anesthesiologist's role in the deep sedation procedure had been assessed solely in terms of costs or comparative effectiveness, using Markov or comparative analysis models.

In sum, by applying the BN to this setting, our findings corroborate evidence, collected otherwise,[26,27] that the

key determinants of a straightforward colonoscopy in the propofol era are the endoscopist's ability and practical experience, whereas the anesthesiologist's experience is not a determining factor.

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