

Original Article

The Use of Pulmonary Artery Catheters and Echocardiography in the Cardiac Surgery Setting: A Nationwide Italian Survey

Filippo Sanfilippo, MD, PhD, EDIC ^{*,†,1}, Alberto Noto, MD[‡],
Valentina Ajello, MD[§],
Blanca Martinez Lopez de Arroyabe, MD, PhD^{||},
Tommaso Aloisio, MD[¶], Pietro Bertini, MD^{**},
Michele Mondino, MD^{††}, Simona Silvetti, MD^{‡‡},
Antonio Putaggio, MD^{§§}, Carlotta Continella, MD^{§§},
Marco Ranucci, MD[¶], Fabio Sangalli, MD^{|||},
Sabino Scolletta, MD^{¶¶}, Gianluca Paternoster, MD^{***}

^{*}University Hospital Policlinico G. Rodolico-San Marco, Catania, Italy

[†]Department of Surgery and Medical-Surgical Specialties, University of Catania, Catania, Italy

[‡]Division of Anesthesia and Intensive Care, Department of Human Pathology of the Adult and Evolutive Age "Gaetano Barresi," Policlinico "G. Martino," University of Messina, Messina, Italy

[§]Department of Cardiac Anesthesia, Tor Vergata University Hospital, Rome, Italy

^{||}Cardiothoracic and Vascular Anesthesia and Intensive Care Unit, Department of Emergency and Intensive Care, University Hospital of Verona, Verona, Italy

[¶]Department of Cardiothoracic and Vascular Anesthesia and Intensive Care Unit (ICU), Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) Policlinico San Donato, Milan, Italy

^{**}Department of Anesthesia and Critical Care Medicine, Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy

^{††}"De Gasperis" Cardio Center, ASST Grande Ospedale Metropolitano Niguarda, Milan, Italy

^{‡‡}Department of Cardiac Anesthesia and Intensive Care, Ospedale Policlinico San Martino IRCCS-IRCCS Cardiovascular Network, Genova, Italy

^{§§}School of Anesthesia and Intensive Care, University Magna Graecia, Catanzaro, Italy

^{|||}Department of Anesthesia and Intensive Care, Azienda Socio-Sanitaria Territoriale Valtellina e Alto Lario, Sondrio, Italy

^{¶¶}Department of Emergency-Urgency, University Hospital of Siena, Siena, Italy

^{***}Department of Cardiovascular Anesthesia and ICU, San Carlo Hospital, Potenza, Italy

Objective: Wide variations exist in the use of pulmonary artery catheters (PACs) and echocardiography in the field of cardiac surgery.

Design: A national survey promoted by the Italian Association of Cardio-Thoracic Anesthesiologists and Intensive Care was conducted.

Setting: The study occurred in Italian cardiac surgery centers (n = 71).

Participants: Anesthesiologists-intensivists were enrolled.

Interventions: Anonymous questionnaires were used to investigate the use of PACs and echocardiography in the operating room (OR) and intensive care unit (ICU).

This study is dedicated to the memory of our wonderful colleague and friend, Dr. Blanca Martinez Lopez de Arroyabe, who prematurely passed away. Blanca was an invaluable member of the ITACTAIC and will be deeply missed.

The list of collaborators for this study is reported in Appendix 1.

¹Address correspondence to Filippo Sanfilippo, MD, University Hospital Policlinico, G. Rodolico-San Marco, Catania, Italy.

E-mail address: filipposanfi@yahoo.it (F. Sanfilippo).

Measurements and Main Results: A total of 257 respondents (32.2% response rate) from 59 centers (83.1% response rate) participated. Use of PACs seems less common in ORs (median insertion in 20% [5–70] of patients), with slightly higher use in ICUs; in about half of cases, it was the continuous cardiac output monitoring system of choice. Almost two-thirds of respondents recently inserted at least one PAC within a few hours of ICU admission, despite its need being largely preoperatively predictable. Protocols regulating PAC insertion were reported by 25.3% and 28% of respondents (OR and ICU, respectively). Transesophageal echocardiography (TEE) was performed intraoperatively in >75% of patients by 86.4% of respondents; only 23.7% stated that intraoperative TEE relied on anesthesiologists. Tissue Doppler and/or 3D imaging were widely available (87.4% and 82%, respectively), but only 37.8% and 24.3% of respondents self-declared skills in these modalities, respectively; 77.1% of respondents had no echocardiography certification, nor were pursuing certification (various reasons); 40.9% had not attended recent echocardiography courses. Lower PAC use was associated with university hospitals (OR: $p = 0.014$, ICU: $p = 0.032$) and with lower interventions/year (OR: $p = 0.023$). Higher independence in performing TEE was reported in university hospitals (OR: $p < 0.001$; ICU: $p = 0.006$), centers with higher interventions/year (OR: $p = 0.019$), and by respondents with less experience in cardiology (ICU: $p = 0.046$).

Conclusion: Variability in the use of PACs and echocardiography was found. Protocols regulating the use of PACs seem infrequent. University centers use PACs less and have greater skills in TEE. Training and certifications in echocardiography should be encouraged.

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Key Words: Swan-Ganz catheter; cardiac anesthesia; coronary artery bypass; hemodynamic monitoring

Since its introduction into clinical practice over 50 years ago,¹ the pulmonary artery catheter (PAC) has been widely used in cardiac surgery and critical care settings for its ability to provide the most advanced, accurate, and precise hemodynamic monitoring.^{2–4} The PAC remains the only tool to simultaneously offer data on continuous right ventricular cardiac output (CO) monitoring, pulmonary arterial pressures, and estimation of left atrial pressure and mixed venous oxygen saturation.⁵ The PAC is considered the gold standard for advanced hemodynamic monitoring; however, the current literature is conflicting regarding its benefits for patient outcomes.^{6–8} Subsequent technological progress has provided clinicians the opportunity for less invasive advanced hemodynamic monitoring through the use of peripheral arterial catheters (most commonly placed at radial or femoral sites). Considering the possible complications associated with PACs (including arrhythmias, sepsis, thrombosis, iatrogenic pulmonary artery rupture, and many others^{9,10}), and the lack of clear supporting evidence,^{7,8} its use has gradually declined since the beginning of the 1990s in critically ill patients,^{11–13} becoming less common outside the cardiac surgery setting.

Despite the pivotal role of PACs in the perioperative management of the most fragile and complex cardiac surgery patients,^{14–16} the exponential growth of perioperative echocardiography led to a further decrease in its use. Indeed, the ability to perform a transesophageal echocardiography (TEE) examination has become an almost indispensable skill for cardiac anesthesiologists, allowing hemodynamic monitoring (though not continuous) with simultaneous accurate assessment of cardiac function and anatomy and information on valve function.^{17–20} Notably, there has been a significant improvement in echocardiographic technology (growing image quality, availability of tissue Doppler imaging [TDI], and real-time 3D), but several barriers remain for cardiac anesthesiologists willing to master the use of TEE. The current shortage of anesthesiologists in Italy does not facilitate their embarking upon the accreditation process (eg, need to study, attend courses, and collect cases for the logbook with adequate

supervision). Receiving institutional support for the accreditation process is challenging, relying on strong efforts by individuals. Moreover, the impression of the current panel is that, in the current landscape, holding a TEE accreditation and achieving advanced skills in TEE do not seem valued in terms of career progression. The use of TEE and PACs should not be seen as mutually exclusive but rather as complementary and synergic in the perioperative management of cardiac surgery patients. However, it is unclear how the two technologies are integrated into current clinical practice. A nationwide survey was conducted among cardiac anesthesiologists in Italy, investigating the use of PACs and TEE in the setting of cardiac surgery, with the hypotheses that the use of PACs is declining, and TEE is largely used, although accreditation in TEE is likely far from being common or valued in the field.

Materials and Methods

This study was designed by the study group of the Italian Association of Cardio-Thoracic Anesthesiologists and Intensive Care (ITACTAIC). An online anonymous survey was planned for anesthesiologists working in cardiac surgery. Email addresses were gathered previously for another survey.²¹ An update of the email addresses was conducted by eight authors who personally contacted the centers with active cardiac surgery departments, contacting the Chiefs of Anesthesia via email or telephone. Email addresses for all anesthesiologists who spent at least part of their duties in the cardiac anesthesia setting (operating room [OR], or intensive care unit [ICU]) were requested. Among 71 centers with an active cardiac surgery department, 838 email addresses for cardiac anesthesiologists, which is greater than the pool of contacts in the previous survey (670 contacts from the same number of centers), were obtained.

An internal pilot was conducted among members of the ITACTAIC Board, who completed the survey to identify critical aspects before distributing it to the mailing list. Once this check was completed and the ITACTAIC Board was satisfied regarding the clarity of questions and completeness of possible

answers, the survey was distributed anonymously through a dedicated website with coded personal mail invitations. The final survey was sent for the first time on May 19, 2022, with three further reminders sent to those who had not yet completed the survey. The last reminder was sent on September 13, 2022.

The questionnaire is provided in the Supplementary Materials (translated into English from Italian) and consists of six parts. The first gathered information on the workplace, type of hospital, affiliation with a university, type of cardiac surgery and performance of transplants and extracorporeal circulatory assistance along with the number of interventions, and presence of residents. The second and third parts asked participants about their use of PACs and continuous hemodynamic assessment in the OR and ICU, respectively. Similarly, the fourth and fifth sections focused on the use of echocardiography in the OR and ICU, respectively. In particular, the intraoperative section focused on TEE, while the ICU-related section contained questions regarding transthoracic echocardiography (TTE). The sixth part consisted of questions regarding the certification of echocardiography skills and attendance at echocardiography courses.

Statistical Analysis

Statistical analyses were performed using SPSS Statistics 17 for Windows. Categorical variables are shown as numbers and percentages. Continuous variables are presented as means $\pm$ standard deviations (SDs) or medians and interquartile ranges (IQRs), according to the distribution, tested with the Kolmogorov-Smirnov test.

A post-hoc analysis was conducted to explore factors associated with greater use of PACs or TEE, both in the OR and ICU. For the use of PACs, respondents were categorized as those using PACs in more (high use) or less (low use) than 50% of cases of advanced hemodynamic monitoring. For analysis regarding the use of TEE on their own or with support from cardiologists, the respondents were divided into two groups based on those performing TEE on their own in over 90% of cases compared with those requiring greater support from cardiologist colleagues. The following factors potentially associated with greater use of PACs or with higher independence in performing TEE were explored: (1) number of interventions performed per year in their center, (2) years of experience in cardiac anesthesia, (3) working in a university hospital, (4) presence of a protocol regulating the use of PACs, (5) number of echocardiography courses attended in the last 5 years, and (6) echocardiography accreditation. Univariate analysis was conducted using the Wilcoxon rank-sum test or Chi-square test, as appropriate.

Results

Invitations were sent via email to 838 Italian cardiac anesthesiologists, but 36 emails were undeliverable (due to anti-spam filters or wrong email addresses); hence, 802 cardiac anesthesiologists were successfully reached. Three reminders were sent and 261 cardiac anesthesiologists completed the survey (32.5%). After the removal of 4 respondents who were not actively working in cardiac anesthesiology, a sample of 257

Table 1
Professional Characteristics of Respondents.

Characteristic		
Cardiac anesthesia experience, y		9 (3-17)
Working with residents	Yes	241 (93.77%)
	No	16 (6.23%)
Cardiac surgery interventions, estimated n/y by each respondent		500 (400-750)
Type of cardiac surgery	Only adults	215 (83.65%)
	Only pediatrics	2 (0.78%)
	Both	40 (15.56%)
Cardiac transplantation/y	1 or more	78 (30.35%)
	None	179 (69.65%)
LVAD implantation/y	(in those performing it)	20 (15-25)
	1 or more	136 (52.92%)
	None	121 (47.08%)
ECMO VA implantation/y	(in those performing it)	10 (5-15)
	1 or more	250 (97.28%)
	None	7 (2.72%)
ECMO VV implantation/y	(in those performing it)	10 (5-25)
	1 or more	193 (75.10%)
	None	64 (24.90%)
	(in those performing it)	5 (2-10)

NOTE. According to distribution, continuous variables are expressed as mean $\pm$ standard deviation or median and interquartile range; categorical variables are presented as numbers and percentages.

Abbreviations: ECMO VA or VV, venoarterial or venovenous extracorporeal membrane oxygenation; ICU, intensive care unit; LVAD, left ventricular assist device; NHS, national healthcare system.

respondents (32.2%), with at least 1 respondent from 59 of the 71 (83.1%) centers, was analyzed.

Characteristics of Respondents and Centers

Data regarding the characteristics of colleagues responding to the survey and their centers are reported in Table 1 and Figs 1 and 2. Over half of respondents worked in the north of Italy ($n = 146$, 56.8%), followed by the south ($n = 60$, 23.4%), and center ($n = 51$, 19.8%), a pattern similar to the previous survey²¹ and in line with the distribution of cardiac surgery centers in Italy. More than one-third of respondents were specialists for 6-15 years (33.8%); overall, respondents stated an average experience in cardiac anesthesia of 9 years [3-17]), and the vast majority worked with the presence of residents (93.8%), with adult cardiac surgery patients (83.6%) or both adults and pediatric cases (15.6%). Respondents mainly worked in university hospitals (40.5%), followed by public hospitals with or without university affiliation (29.2% and 7.8%, respectively). The median number of cardiac surgery interventions per center was 500 (400-750) per year.

Use of PAC in Cardiac Surgery ORs and ICUs

A total of 220 cardiac anesthesiologists (87.6%) answered that they used PACs in the cardiac surgery OR, with a median insertion of PACs in 20% (5-70) of patients. For those using PACs, a protocol regulating its insertion in the OR was present

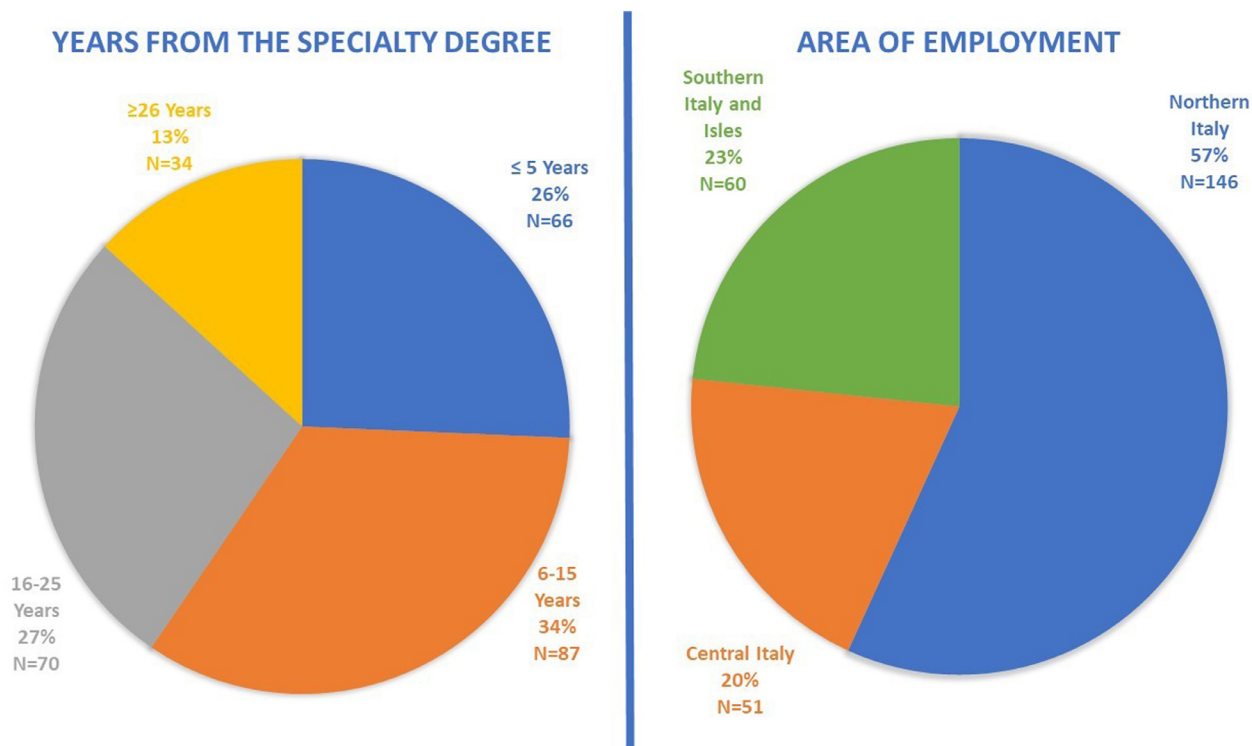


Fig 1. Pie charts showing the distribution of respondents according to years from achieving their specialty degree in anesthesiology (*left*) and geographical area of employment (*right*). Results are reported as numbers and percentages.

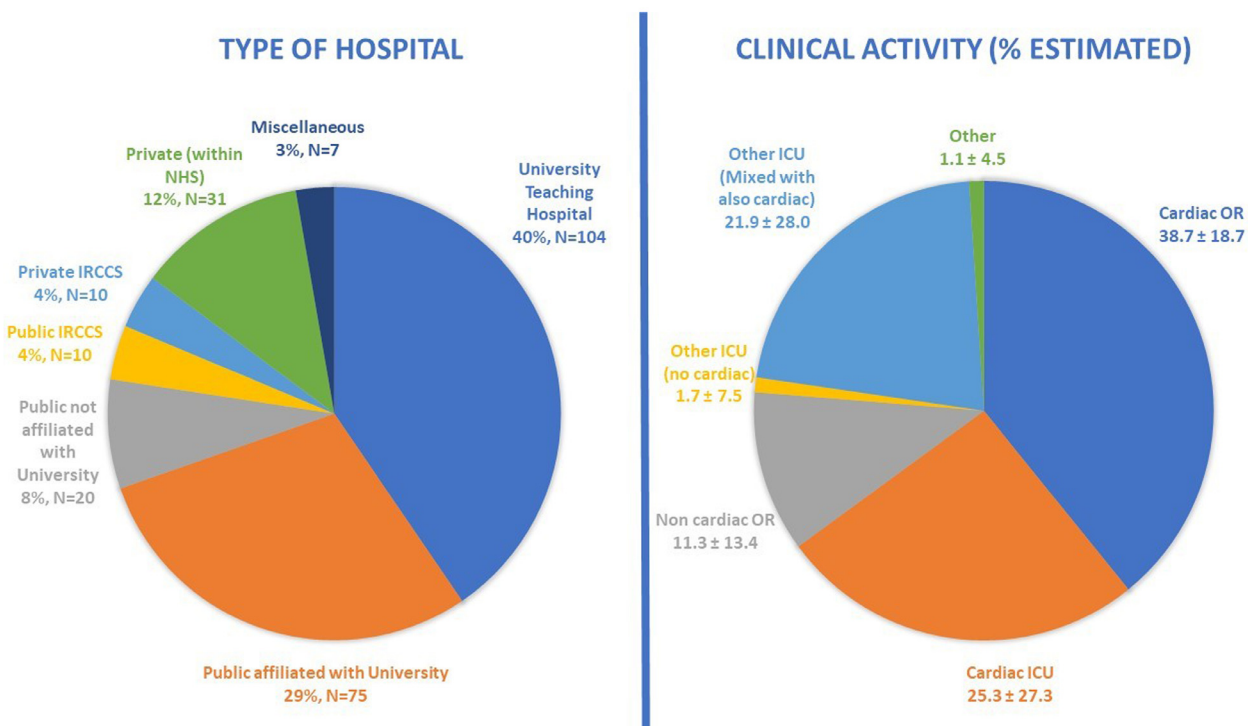


Fig 2. Pie charts showing the distribution of respondents according to type of hospital (*left*) and organization of clinical activity (*right*). Results are reported as numbers and percentages. ICU, intensive care unit; IRCCS, Institutes for Hospitalization and Care of Scientific Model ("Istituti di Ricovero e Cura a Carattere Scientifico"); NHS, national healthcare system; OR, operating room.

in only one-quarter of cases (25.3%), and the decision was discussed in a team with the cardiac surgeon by 32.3% of respondents. Compared with traditional cardiac surgery with full sternotomy, in patients undergoing minimally invasive cardiac surgery, PACs were used never (35.4%), to the same extent (28%), always (20.2%), and less or more frequently (14.8% or 1.6%, respectively). Similarly, changes in the approach to the use of PACs during off-pump coronary artery bypass grafting were investigated. PACs were not used in cases of off-pump by over one-third (37.4%), and were used to similar extent, less, or more frequently by 36.2%, 19.6%, and 6.8%, respectively.

In the ICU, 55.1% of respondents reported they use PACs in $\leq 25\%$ of patients, followed by 21.5% in 26%-50% of patients, 3.6% in 51%-75% of the population, and 19.8% in $>75\%$ of patients. When addressing the use of PACs compared with other options for advanced continuous CO monitoring, PACs were used in $<25\%$ of the entire number of advanced CO monitoring situations by 28.5% of respondents, in 26%-50% of monitoring situations by 18.5%, in 51%-75% by 13.2%, and $>75\%$ by 39.7% of respondents. Hence, PAC was the predominant advanced continuous CO monitoring system reported by 52.9% of respondents.

Interestingly, 63.6% of respondents reported that, in the last year, they inserted a PAC in the first few hours after ICU admission in cardiac surgery patients when the need for a PAC was largely predictable according to preoperative conditions. However, for most respondents, this was a situation encountered in a minority of ICU admissions. A protocol regulating the use of PACs in the ICU was reported by 28% of respondents, with shared team decisions made with cardiac surgeons and/or cardiologists reported by 32.8% of respondents. Among those not performing team decision-making in these cases, 54.6% affirmed that a preoperative plan and discussion in this regard would be beneficial.

Use of Echocardiography in Cardiac Surgery ORs and ICUs

The survey questioned which professionals oversaw the performance of TEE during cardiac surgery in the OR. A total of 23.7% of respondents stated that oversight relied on anesthesiologists only; in most cases, it was performed by anesthesiologists and/or cardiologists (74.3%), and 2% responded it was performed by cardiologists only. The two most frequent indications reported for requesting collaboration by a cardiologist in performing an intraoperative TEE were perivalvular leaks ($n = 181$, 70.4%) and mitral regurgitation ($n = 106$, 41.2%), followed by other conditions with a lower frequency of cardiological consult request. The performance of a TEE examination was reported in over 75% of patients by 86.4% of respondents, and only 1.2% reported a TEE examination in $\leq 25\%$ of cardiac surgery patients. Of those not reporting use in all cases, only 30% reported the presence of a protocol stating the type of patients receiving an intraoperative TEE examination. The vast majority reported that the TEE machine in the OR was equipped with TDI and 3D functions (87.4% and 82%, respectively). Regarding the ability to perform and/or interpret TDI imaging, 37.8% reported both skills, 20.7% reported being in training for it, 11% were able to acquire or

interpret only, and 20.3% could do neither. Similarly, regarding the ability to perform and/or interpret 3D imaging, 24.3% reported both skills, 37.4% reported a phase of training for this skill, 11.5% were able to acquire or interpret only, and 26.7% could do neither.

Regarding the performance of TEE in the ICU, 9.7% reported exclusive execution by anesthesiologists and 58.4% reported that only on rare occasions was a cardiologist involved. Conversely, 17.9% reported that anesthesiologists and cardiologists perform TEE in the ICU with roughly equal frequency, and 14% reported that TEE was mostly performed by cardiologists.

A daily or almost daily echocardiographic examination in the ICU after cardiac surgery was reported by 57.2% (TTE) and 1.6% (TEE) of respondents; surprisingly, a routine check with echocardiography before discharge from the ICU was reported by roughly one-quarter of respondents (23.3%), meaning either a partial misinterpretation of the question or that echocardiography before discharge was not performed if the examination was done the day before. It is also possible that respondents performed echocardiograms on almost a daily basis but the practice of their colleagues was different (less keen on performing echocardiograms). Further, there is a chance that respondents may have felt “wrong” if they had not stated they performed a daily (or almost daily) echocardiographic examination after cardiac surgery, hence reducing the reliability of the findings, but this could not be determined. Regarding preferences, 87.5% of respondents favored starting with TTE before performing a TEE in the ICU.

Echocardiography Accreditation and Courses

Most respondents had no echocardiography certifications ($n = 198/257$, 77%). At least one echocardiography accreditation was endorsed by 20.2% of respondents (total $n = 52$; $n = 31$ TEE, $n = 9$ TTE, $n = 12$ both). Eleven respondents (4.3%) were acquiring an accreditation ($n = 7$ with no prior accreditation, $n = 3$ already TEE accredited, $n = 1$ already TTE accredited). The main reason(s) identified by respondents to justify the absence of a TTE and/or TEE accreditation were the lack of protected time to study ($n = 94$, 36.6%), lack of time to collect cases ($n = 66$, 25.7%), belief that accreditations are not valued for career progression ($n = 52$, 20.2%), and the judgment that clinical experience gathered with daily practice is enough ($n = 31$, 12.1%). The participants reported a median of 5 (4-12) years since they achieved accreditation. They held accreditations for 6 (3-8) years.

Regarding the 43 respondents reporting a TEE accreditation, 41.9% ($n = 18$) reported an accreditation with ITACTAIC, followed by 37.2% ($n = 16$) with European Association of Cardiothoracic Anaesthesiologists and Intensive Care, European Association of Cardiovascular Imaging accreditation, 11.6% ($n = 5$) with Società Italiana di Ecocardiografia e CardioVascular Imaging accreditation, 7.0% ($n = 3$) with National Board of Echocardiography, American Society of Echocardiography accreditation 7.0% ($n = 3$) with Società Italiana Anestesia, Analgesia, Rianimazione e Terapia Intensiva accreditation, and 2.3% ($n = 1$) with a foreign university accreditation. For

Table 2
Results of Univariate Analysis Exploring Factors Associated With Greater Use of PACs or Greater Independence in the Use of TEE by anesthesiologists in the OR and ICU.

OR	PAC Use			Independence With TEE		
	High N = 57	Low N = 194	p	High N = 167	Low N = 90	p
Cardiac experience, y	7 (3, 16)	9 (4, 18)	0.600	8 (3, 17.5)	9.5 (4, 17)	0.700
Cardiac interventions/y	475 (350, 700)	500 (400, 900)	0.023	500 (400, 800)	475 (350, 700)	0.019
University hospital	19/64 (30%)	91/193 (47%)	0.014	87/167 (52%)	23/90 (26%)	<0.001
Presence of PAC protocol in OR	10/28 (36%)	50/186 (27%)	0.332	41/146 (28%)	19/68 (28%)	0.983
Echocardiography courses, n	1 (0, 2)	1 (0, 2)	0.472	1 (0, 2)	1 (0, 2)	0.893
Echocardiography accreditation, n	13/57 (23%)	45/194 (23%)	0.951	39/167 (23%)	20/90 (22%)	0.837

ICU	PAC Use			Independence with TEE		
	High N = 58	Low N = 189	p	High N = 175	Low N = 82	p
Cardiac experience, y	6 (2, 16)	9.5 (4, 18)	0.282	7 (3, 16)	11 (5, 20)	0.046
Cardiac interventions/y	500 (350, 750)	500 (400, 762.5)	0.282	500 (400, 800)	475 (350, 737.5)	0.071
University hospital	22/69 (32%)	88/188 (47%)	0.032	85/175 (49%)	25/82 (30%)	0.006
Presence of PAC protocol in ICU	11/26 (42%)	49/188 (26%)	0.084	48/162 (30%)	12/52 (23%)	0.360
Echocardiography courses, n	1 (0, 2)	1 (0, 2)	0.480	1 (0, 2)	0 (0, 2)	0.606
Echocardiography accreditation, n	15/58 (26%)	44/189 (23%)	0.687	38/175 (22%)	21/82 (26%)	0.489

NOTE. Results are expressed as median and interquartile range (continuous variables) or as numbers and percentages (categorical variables). Analyses were conducted using Wilcoxon rank-sum or Chi-square tests according to variable type. Abbreviations: ICU, intensive care unit; OR, operating room; PAC, pulmonary artery catheter; TEE, transesophageal echocardiography.

TTE accreditations, most were by the Società Italiana di Ecocardiografia e CardioVascular Imaging (47.6%, n = 10).

In the last 5 years, 40.9% of respondents reported never attending an echocardiography course. Of those attending at least 1 course, the median was 2 (1-3), and the majority reported going to on-site courses (72.4%), followed by both on-site and online (9.2%), and both modalities (18.4%).

Factors Associated With Greater Use of PACs or TEE

Factors deemed possibly associated with greater or lower use of PACs and characteristics linked to greater independence in TEE by anesthesiologists-intensivists were explored. As shown in Table 2, greater independence of anesthesiologists in performing TEE in the OR is associated with university hospitals (52% v 26%, $p < 0.001$) and with greater numbers of procedures per year (500 [400-800] v 475 [350-700], $p = 0.019$); similarly, in the ICU, independence in performing TEE examination was associated with working in university hospitals (49% v 30%, $p = 0.006$) and to fewer years of experience in cardiac anesthesia (7 [3-16] v 11 [5-20], $p = 0.046$).

Academic hospitals also seemed to show less use of PACs in the OR (30% v 47%, $p = 0.014$) and ICU (32% v 47%, $p = 0.032$).

Discussion

In this nationwide survey conducted in the setting of cardiac anesthesia regarding the use of PACs and echocardiography, both in the OR and ICU, respondents predominantly reported

over 5 years of experience (median 9 years), working in university hospitals (40%) or in centers affiliated with universities (29%) and, in almost 95%, usually working with residents. This survey identified several interesting aspects of current clinical practice in the use of PACs and echocardiography.

PACs

In the OR, the use of PACs was reported in about one in five patients, and its use seems to further decrease in certain procedures, as in the case of minimally invasive (ministernotomy or minithoracotomy) cardiac surgery or for off-pump coronary artery bypass grafting. Similarly, its use in the ICU is mostly reported in a minority of patients. The presence of protocols regulating the use of PACs was reported by roughly one-quarter of respondents. Furthermore, discussion in multidisciplinary teams was reported by less than one-third of respondents. Hence, it seems that the decision on the insertion of a PAC currently relies predominantly on the choice of the attending physician. In post-hoc analysis exploring factors linked to greater use of PACs, the presence of a protocol regulating its use was not associated with differences in use. A report from the Critical Care Cardiology Trials Network in North America showed wide variation in the use of PACs in the years 2017 to 2021, with use of PACs reported between 8% and 73% in patients admitted to cardiac ICUs with shock; such a large difference was not fully explained by patient level-factors, and the authors concluded that this finding appeared driven, at least in part, by institutional tendency. Notably, the data also suggested that management with PACs in patients presenting with

shock and admitted to the cardiac ICU may be associated with lower mortality.² As this survey was anesthesiologist-centered rather than institution-centered, the results could have been skewed by greater participation from some centers than others, though at least one response was received from most centers. Interestingly, most respondents (almost 95%) worked with residents, and this could have influenced the results. Indeed, a previous survey on the use of PACs in the United States from 2010 to 2014 showed that the presence of residents or certified nurse anesthetists was among the factors associated with the increased likelihood of PAC use.¹⁴ Although this may be seen as a bias, one has to consider that, in the Italian landscape of cardiac surgery, most centers are affiliated with universities and a minority are private institutions; even so, residents are often sent to private centers under agreements with their university.

Half of respondents seemed aware that the absence of protocols is suboptimal and reported that a preoperative discussion on this topic would be beneficial. It was also surprising that almost two-thirds of respondents working in cardiac ICUs stated that, over the last year, they had to insert a PAC in the first few hours after admission, despite having judged that this requirement was largely predictable based on preoperative conditions. Overall, it seems that communication and teamwork should be potentiated, possibly by introducing local policies to establish which preoperative conditions suggest the use of PACs.

Echocardiography

Regarding the use of echocardiography, and more specifically of TEE, extensive intraoperative use was found among respondents. Indeed, 61% performed TEE in all cases and, in general, over 85% performed TEE in more than three-quarters of cases. This use may be in line with some reports²² and higher than others.^{23,24} The use of TEE showed significant nationwide variations in an Indian survey among cardiac anaesthesiologists.²⁵

Like what has been reported for PACs, a protocol regulating the use of intraoperative TEE was reported by a minority of those not performing TEE in all cardiac surgical cases. Interestingly, differences were found in the approach to TEE between the OR and ICU, with support from cardiologists more common in the OR, where less than one-quarter of respondents stated that TEE was performed by anesthesiologists only. Notably, only 35 respondents (13.9%) feel confident enough in TEE that they never request support from cardiologists in the OR; conversely, 106 respondents (42.2%) stated they may request support from the cardiologist for mitral valve insufficiency, a condition commonly encountered, which is not surprising since its assessment under general anesthesia is clinically challenging.²⁶

In the ICU, most respondents stated that TTE is the first-line echocardiographic approach, with only 15 respondents going straight to TEE and the others preferring to start with TTE. Echocardiography in the ICU was more commonly performed by anesthesiologists, and less than 15% of respondents reported a preponderance of echocardiography examinations performed by cardiologists. Echocardiography has the

apparent value of noninvasively providing clinically relevant information that cannot be gathered with use of “non-PAC” CO monitoring (ie, right ventricular function, left atrial pressure, valve disease); the widespread ability of respondents to perform TEE in the ICU independent of help from cardiologists may be explained by the frequent need to perform TEE in conditions of urgency or emergency. Indeed, requesting a cardiology consultation to rule out the diagnosis of cardiac tamponade may result in loss of time and significant clinical deterioration of the patient. Interestingly, respondents also reported widespread use of daily (or almost daily) echocardiography in the ICU, with almost 60% stating that a daily examination was performed in all patients. However, only 23.3% of respondents reported that an echocardiography examination was always performed before transferring a cardiac surgery patient to the ward in their institution.

Equipment and Competencies in Echocardiography

TEE machines available in the OR were reported to be equipped with TDI and 3D imaging software by most respondents (>80%). However, around one in five did not feel able to perform and interpret TDI imaging, while less than 40% were confident using TDI. Similarly, around one in four respondents were unable to use 3D functions, and less than 25% felt confident in 3D echocardiography.

In terms of accreditation, three-quarters of respondents (n = 197/257) stated they had no echocardiography accreditation, and only 7 were pursuing an accreditation (TTE). Of the 46 respondents reporting an accreditation, 14 had a double accreditation (TTE and TEE), and 32 and 12 held a TEE or TTE accreditation, respectively. The authors' association was the most common source of TEE accreditation in Italy (n=18/46).

A survey of the Society of Cardiovascular Anesthesiologists showed an increase in TEE accreditation from 69% to 90% from 2010 to 2020, reflecting the importance of accreditation in the United States where, nowadays, TEE accreditation is an essential requisite to apply for a staff position in cardiac anesthesia.²⁷ In this regard, Italy and several other countries are far behind. Introducing a mandatory need for TEE accreditation to work in cardiac anesthesia is not as easy as it may seem, especially in a period of lack of human resources. Moreover, clinicians require a greater degree of training for echocardiography compared with, for instance, that needed to master the use of PACs.¹⁹ Hence, there is huge demand for courses and training to properly master TEE in the setting of cardiac anesthesiology,²⁸ but several limitations to the universal adoption of TEE in cardiac surgery have been identified.²² In the current survey, from motivational perspectives, lack of time to study and/or collect cases was the greatest driver of the absence of accreditation; however, one-quarter of respondents stated that a lack of value for career progression was a reason for not starting the process of accreditation. In the last 5 years, over 40% had never attended an echocardiography course, reflecting a sort of disengagement with this subject. The authors posit that, while it is currently challenging to provide clinicians protected time to study and collect cases for accreditation, a

reconsideration of the value of accreditation should be undertaken, and should not be ignored at the institutional level.

Factors Associated With Use of PACs or TEE

A post-hoc analysis was conducted to explore factors linked to greater use of PACs and/or greater independence of anesthesiologists-intensivists in the use of TEE. Such results reflect a grossly specular approach. Indeed, even if PACs and TEE should be seen as additive and possibly synergic in hemodynamic optimization, anesthesiologists-intensivists working in university hospitals used PACs to a lesser extent and showed greater independence in the use of TEE, in both the OR and ICU. Moreover, respondents working in centers performing more interventions per year showed similar results for the OR setting (lower use of PACs and greater independence in TEE). The latter is unsurprising as university centers are usually larger and have greater surgical volumes. The results obtained regarding the use of PACs and independence in TEE seem specular, and may indirectly support the idea that greater skills in TEE may prompt a lesser need for PACs.

The current authors are not entirely surprised by these results as university hospitals have greater human resources with constant availability of residents; moreover, in these centers, there could be more opportunities for training in echocardiography. In turn, hospitals with lower staffing resources could offer fewer openings and chances for learning TEE. Moreover, performing TEE independently requires not only skills that are more complex to learn compared with a PAC, but also should be balanced with the obvious need to provide anesthesia. Hence, PACs may have the advantage of a faster learning curve while offering continuous hemodynamic monitoring, leaving the anesthesiologist hands-free for tasks.

In the ICU setting, there was greater independence in performing TEE without calling for cardiologist support in respondents with fewer years of experience in cardiology. This result may reflect the greater inclination in newer generations to learn echocardiography, though the use of PACs and independence in TEE were not associated with attendance to echocardiography courses in the last 5 years, nor with accreditation in echocardiography.

Limitations

Several limitations of the current work must be considered. Despite enlarging the sample of email addresses of cardiac anesthesiologists compared with the previous survey, a slightly lower response rate was observed, despite reaching at least one respondent in over 80% of centers. Difficulties in reaching certain centers were encountered while gathering colleagues' institutional emails. In this case, antispam filters may have blocked some emails (as stated by some centers). It is also possible that the institutional email is not regularly checked, or that difficulties were encountered when being redirected to the website for the questionnaire (as stated by some centers). Nonetheless, a response rate over 30% should be regarded as very good as surveys involving physicians usually have much

lower return rates. Second, the respondents were mainly experienced cardiac anesthesiologists working in the public sector with residents. Results should be contextualized given the respondents' characteristics. Moreover, this survey is clearly limited by its national design, and the findings are not automatically transferable to other contexts outside Italy. Third, some of the answers may have been affected by the recent pandemic that reduced the number of cases and the possibility of attending courses. Fourth, several more questions could have been asked, but the authors chose to limit the number of questions to increase the response rate and feasibility of the survey. For instance, a breakdown of the use of PACs or TEE according to the type of surgery was not conducted. Fifth, there could be a bias in respondents as it is possible that those more likely to use PACs or TEE might have been more inclined to participate in the survey, but there is no data to support or reject this hypothesis. Hence, "non-response bias" could not be evaluated, meaning that nonresponders could differ meaningfully from responders. This bias has been demonstrated to be a serious concern in survey studies, especially if the response rate is low. Such bias may have been limited by the decision to design the survey with simultaneous exploration of attitudes toward the use of both PACs and TEE, both in ORs and ICUs, to produce greater participation by anesthesiologists-intensivists hesitating in a balanced survey. Sixth, the question regarding the use of PACs in cases of off-pump coronary artery bypass grafting or minimally invasive cardiac surgery was somewhat misleading regarding potential overlap between utilization always or never, which still could be lower, equal, or higher compared with cardiac surgery conducted with full sternotomy. Seventh, this investigation has all the limitations common to surveys, and there is a risk of bias among respondents.

Conclusions

In a nationwide survey, anesthesiologists reported that PACs were used in one-fifth of patients in the cardiac OR; in this regard, it is likely that the increasing use of TEE had a major role. The use of PACs is reported to be more frequent in the ICU, where it seems slightly more common compared with other continuous CO monitoring methods, though with wide variability. Support from a cardiologist for TEE was much more commonly requested in the OR than in the ICU setting. A protocol regulating the use of PACs and TEE was rarely described. The echocardiography machines available seem mostly equipped with TDI and 3D imaging software, but a minority of respondents seem able to use these functions properly. Three-quarters of respondents had no echocardiography accreditation, and the need to enhance echocardiography training is apparent.

Declaration of competing interest

The authors declare no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Filippo Sanfilippo: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Alberto Noto:** Writing – review & editing, Writing – original draft, Supervision, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Valentina Ajello:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Blanca Martinez Lopez de Arroyabe:** Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Tommaso Aloisio:** Writing – review & editing, Methodology, Investigation, Data curation, Conceptualization. **Pietro Bertini:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Michele Mondino:** Methodology,

Investigation, Data curation, Conceptualization. **Simona Silvestri:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Antonio Putaggio:** Writing – review & editing, Software, Investigation, Formal analysis, Data curation. **Carlotta Continenza:** Writing – review & editing, Software, Formal analysis, Data curation. **Marco Ranucci:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Fabio Sangalli:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Sabino Scolletta:** Writing – review & editing, Software, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Gianluca Paternoster:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Appendix

The use of Pulmonary Artery Catheter and of Echocardiography in the cardiac surgery setting: a nationwide Italian survey.

List of Collaborators to the ITACTAIC Survey project

Name and Surname	Affiliation
Pierpaolo Dambruoso	Ospedale Santa Maria Bari, GVM Care and Research, Bari, Italy
Domenico Vuoto	Clinica Mediterranea, Napoli, Italy
Arianna Pagano	Azienda Ospedaliera di Rilievo Nazionale e di Alta Specialità San Giuseppe Moscati, Avellino, Italy
Giuseppe Sepolvere	Department of Anesthesia and Cardiac Surgery Intensive Care Unit, Casa Di Cura San Michele, Maddaloni, Caserta, Italy
Francesco Greco	UOC Cardioanestesia e Terapia Intensiva Cardiocirurgica IRCCS Casa Sollievo Della Sofferenza San Giovanni Rotondo, Italy
Santonocito Cristina	Anestesia e Rianimazione, Azienda Ospedaliero-Universitaria Policlinico “G. Rodolico” San Marco, Catania, Italy
Matteo Lucchelli	Anestesia e TI Chirurgica Cardiovascolare ASST Ovest Milanese, Italy
Ricardo Martinez Escobar	Anestesia e Terapia Intensiva Cardiovascolare, Fondazione Poliambulanza Istituto Ospedaliero - Brescia, Italy
Vincenzo Francesco Tripodi	Cardiac Anesthesia and Intensive Care, Great Metropolitan Hospital “Bianchi-Melacrino-Morelli”, Reggio Calabria, Italy
Michelangelo Vitiello	Cardiovascular Anesthesia and ICU, San Carlo Hospital, Potenza, Italy
Francesco Federici	Cardiac Anaesthesia, Sant’Andrea Hospital, Rome, Italy
Andrea Scapigliati	Department of Cardiovascular Medicine, Fondazione Policlinico Universitario A Gemelli IRCCS, Rome, Italy
Valter Casati	Division of Cardiovascular Anesthesia and Intensive Care Policlinico di Monza, Monza, Italy
Anna Chiara Trompeo	A.O.U. Città della Salute e della Scienza di Torino, Torino, Italy
Martina Anguissola	Department of Cardiothoracic and Vascular Anesthesia and ICU, IRCCS Policlinico San Donato, Milan, Italy
Roberto Veronesi	SC AR2 - Anestesia e Terapia Intensiva Cardioracica Fondazione IRCCS Policlinico San Matteo, Pavia, Italia
Daniele Marianello	Department of Medical Science, Surgery and Neurosciences, Cardiothoracic and Vascular Anesthesia and Intensive Care Unit, University Hospital of Siena, 53100 Siena, Italy
Marco Meli	Hesperia Hospital, Modena, Italy
Francesco Corazzi	UO anestesia e Terapia Intensiva IRCCS Multimedica, Sesto San Giovanni, Milano, Italy
Andrea Farinaccio	Department of Cardiac Anesthesia, Tor Vergata University Hospital, Rome, Italy.
Cesira Palmeri di Villalba	UOSD Terapia Intensiva Cardio-Toraco-Vascolare, Azienda Ospedaliera Universitaria Policlinico Giaccone, Palermo, Italy
Fabio Guarracino	Department of Anesthesia and Critical Care Medicine, Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy.
Giovanni Serena	Anestesia e Rianimazione Presidio Ospedaliero Universitario Santa Maria della Misericordia, Udine, Italy
Chiara Gallazzi	Ospedale Galeazzi Sant’Ambrogio, Milano, Italy
Marco Cucurachi	Department of Intensive Cardiovascular Care Unit, Lecce General Hospital, Lecce, Italy
Mauro D’Amora	Department of Cardiac, Thoracic and Vascular Anaesthesia, University Hospital “San Giovanni Di Dio e Ruggi D’Aragona”, Salerno, Italy
Domenico Vitale	Cardiothoracic Vascular Anesthesia and ICU Santa Croce e Carle Hospital, Cuneo, Italy
Beatrice Passavanti	Department of Women, Child and General and Specialized Surgery, University of Campania L. Vanvitelli. Naples, Italy
Matteo Melchionda	Cardiac Anesthesia and Cardiac Intensive Care Unit Mater Dei Hospital Bari, Italy
Chiara Manganelli	Department of Anesthesiology and Intensive Care, University of Rome “La Sapienza,” Rome, Italy.

(continued)

(continued)

Name and Surname	Affiliation
Andrea Wolfler	IRCCS Ospedale Giannina Gaslini, Genoa, Italy
Lorenzo Grazioli	ASST Papa Giovanni XXIII, Dipartimento Emergenza Urgenza e Area Critica, Bergamo, Italy
Ezio Bonanomi	ASST Papa Giovanni XXIII, Anestesia e Rianimazione Pediatrica, Bergamo, Italy
Maria Cristina Conti	UOC anestesia e rianimazione, Fondazione Policlinico Universitario Campus Biomedico, Roma, Italy
Silvia Grossi	Department of Anesthesia and Intensive Care Medicine, Azienda Ospedaliero-Universitaria di Parma, Parma, Italy
Demetrio Pittarello	Institute of Anesthesia and Intensive Care, Padua University Hospital, Padua, Italy
Vinicio Danzi	Department of Anesthesiology and Intensive Care, San Bortolo Hospital, Vicenza, Italy
Leonardo Götting	Cardiothoracic and Vascular Intensive Care Unit, Hospital and University Trust of Verona, Verona, Italy
Daniele Penzo	Department of Anesthesia and Intensive Care, Santa Chiara Hospital, Trento, Italy
Giuseppe Crescenzi	Cardiovascular Department, UO of Cardiac Anesthesia of the IRCCS Humanitas Research Hospital, Rozzano, Italy
Leonello Avalli	Department of Anesthesia and Intensive Care Unit, Unità operativa complessa Anestesia e Rianimazione, Ospedale San Gerardo, Azienda Socio-Sanitaria Territoriale Monza, Monza, Italy
Maria Luisa Contristano	GMV – Istituto Clinico Ligure di Alta Specialità, Rapallo (Genoa), Italy

Supplementary materials

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