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Mapping interventional cardiology in Europe: the second edition of the European Society of Cardiology (ESC)/European Association of Percutaneous Cardiovascular Interventions (EAPCI) Atlas project

Andreas Baumbach[1,2]*, MD, PhD; Anantharaman Ramasamy[1,2], MBChB, MRCP; Christoph Naber[3], MD; Adam Timmis[4,5], MD, PhD; Dariusz Dudek[6], MD, PhD; Dzianis Kazakevich[5], MD, PhD; Radu Huculeci[5]; Victor Aboyans[5,7]; Panos Vardas[5,8], MD, PhD; Emanuele Barbato[9], MD, PhD; and contributing National Cardiac Societies

**Corresponding author: Queen Mary University of London, Barts Heart Centre, St Bartholomew's Hospital, West Smithfield, London, EC1A 7BE, United Kingdom. E-mail: a.baumbach@qmul.ac.uk*

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The European Society of Cardiology (ESC)/ European Association of Percutaneous Cardiovascular Interventions (EAPCI) Atlas in Interventional Cardiology is a joint project between the EAPCI and the ESC[1]. The ESC/EAPCI Atlas is a unique compendium of cardiovascular statistics across ESC member countries, providing a resource for guideline and policy development and an audit tool for the implementation of their recommendations in participating countries.

In this short report, we focus on changes in interventional practice over time, highlighting inequalities between high- and middle-income ESC member countries in Europe.

This is the 2nd ESC/EAPCI Atlas survey, with participation of 35 ESC member countries, expanding upon the 16 countries that contributed to the previous survey[1]. The descriptive statistics, infrastructure and procedure volumes are summarised in **Supplementary Table 1**. Data collection and analysis are reported in **Supplementary Appendix 1**. We acknowledge the contributing working groups and national representatives in **Supplementary Appendix 2**.

Our survey showed wide national variation in the number of catheterisation laboratories per million population, ranging from 1.46 in Ukraine to 12.12 in Germany. Notable changes were seen in Egypt, with an increase, and Denmark, with a reduction, of catheterisation laboratories between 2016 and 2018. Similar heterogeneity was observed in numbers of interventional cardiologists and procedure volumes, with continuing differences across ESC member countries in the penetration of life-saving interventions such as primary percutaneous coronary intervention (PCI) **(Supplementary Table 1)**. Novel structural interventional procedures are generally increasing, particularly in higher-income countries, where they far outnumber those performed in middle-income countries.

All countries with paired 2016 and 2018 data available reported an increase in transcatheter aortic valve implantation (TAVI) procedures, except for Turkey and Greece. The procedure rates were low in middle-income countries, where fewer than 50 TAVI procedures per million people were performed. We found a positive correlation between TAVI implantation and gross national income per capita ($r=0.95$; $p<0.001$) **(Figure 1)**.

Detailed results are summarised and illustrated in **Supplementary Appendix 3**-**Supplementary Appendix 5** and **Supplementary Figure 1**-**Supplementary Figure 17**.

The results of this survey document an ongoing increase in valvular interventions prior to the 2020 pandemic. The rate of coronary intervention appears stable in most developed countries. The wider spectrum of valve procedures, as well as the use of adjunctive coronary procedures, are predominantly present in higher-income countries with a more developed interventional infrastructure. The data we present illustrate the significant penetration of PCI across ESC member countries and provide a benchmark for policymakers developing national interventional services.

Although every effort went into making the maximum data available, we cannot claim completeness of data for

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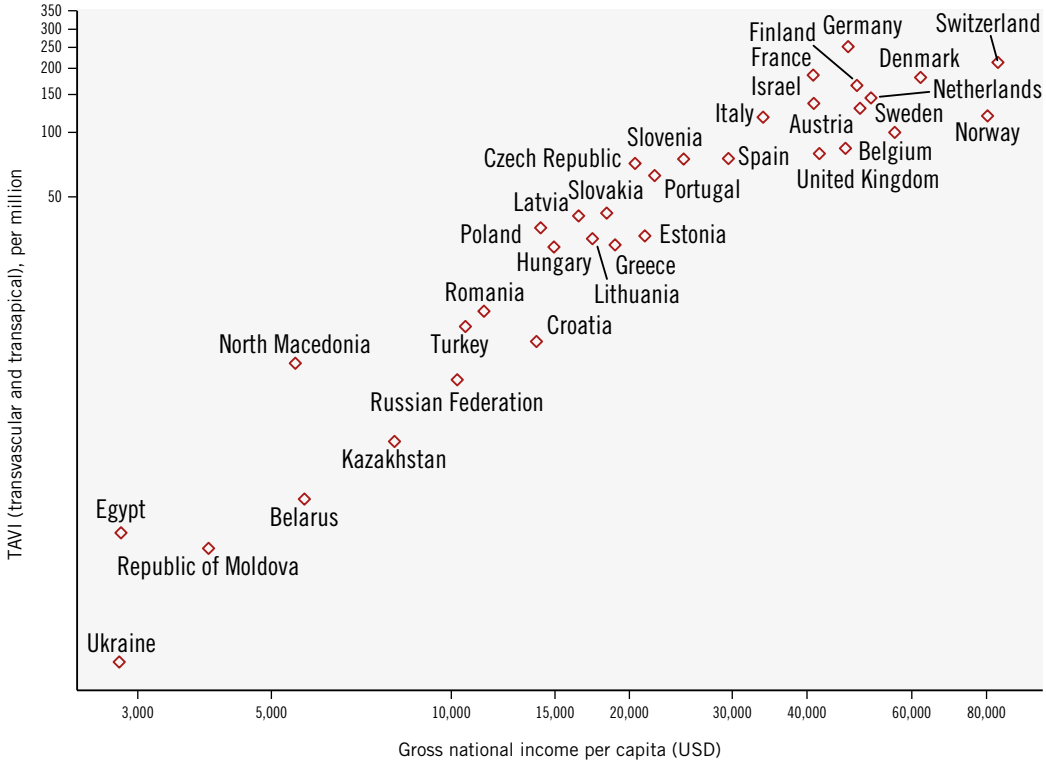

Figure 1. *Transcatheter aortic valve implantation and gross national income across Europe in 2018 (log scale).*

all countries, procedures or infrastructure parameters. Furthermore, differences in the national datasets can make direct comparison difficult. Changes in data acquisition methods in some countries between the first and second editions may lead to inaccuracies in direct comparisons.

This 2nd ESC/EAPCI Atlas survey reports data on infrastructure and procedures in interventional cardiology from 35 participating ESC member countries. This edition will serve as a comparator for the next update, the EAPCI/ESC Atlas 3, which will address the impact of the pandemic on patient access to procedures, as well as the limitations to reporting, during and after the COVID-19 years.

Authors' affiliations

1. Department of Cardiology, Barts Heart Centre, Barts Health NHS Trust, London, United Kingdom; 2. Centre for Cardiovascular Medicine and Devices, William Harvey Research Institute, Queen Mary University of London, London, United Kingdom; 3. Facharztpraxis Baldeney, Essen, Germany; 4. Queen Mary University of London, London, United Kingdom; 5. European Heart Agency, European Society of Cardiology, Brussels, Belgium; 6. Instytut Kardiologii, Uniwersytet Jagielloński, Collegium Medicum, Krakow, Poland; 7. EpiMaCT, Inserm1094 & IRD270, Limoges University, Limoges, France and Department of Cardiology, Dupuytren University Hospital, Limoges, France; 8. Biomedical Research Foundation, Academy of Athens and Heart Sector, Hygeia Hospitals Group, HHG, Athens, Greece; 9. Department of Clinical and Molecular Medicine, Sapienza University of Rome, Rome, Italy

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Conflict of interest statement

A. Baumbach reports personal fees from AstraZeneca, Sinomed, MicroPort, Medtronic, Faraday, Pi-Cardia, Biosensors, JenaValve, and Meril Life Sciences. E. Barbato reports personal fees from Insight Lifetech, Boston Scientific, and Abbott. P. Vardas reports personal fees from the ESC and Hygeia Hospitals Group. The other authors have no conflicts of interest to declare.

Reference

1. Barbato E, Noc M, Baumbach A, Dudek D, Bunc M, Skalidis E, Banning A, Legutko J, Witt N, Pan M, Tilsted HH, Nef H, Tarantini G, Kazakiewicz D, Huculeci R, Cook S, Magdy A, Desmet W, Cayla G, Vinereanu D, Voskuil M, Goktekin O, Vardas P, Timmis A, Haude M. Mapping interventional cardiology in Europe: the European Association of Percutaneous Cardiovascular Interventions (EAPCI) Atlas Project. *Eur Heart J.* 2020;41:2579-88.

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The supplementary data are published online at: https://eurointervention.pcronline.com/doi/10.4244/EIJ-D-24-00342

Supplementary data

Supplementary Appendix 1. Data collection policy.

Data collection and quality assurance
Individual participating country data were collected by the National cardiac Society (NCS) via local inquiry or national registries and recorded in an electronic case report form (e-CRF). The existing ESC-Atlas platform was used to consolidate data collection.

Data presentation
Data are for 2018 or latest year available and adjusted for population size by reporting values per million people. The national income status for the 35 participating counties, defined by the World Bank classification for as follows:

- Lower-middle income: Gross national income (GNI) 3995;
- Upper-middle income: GNI 3996-12375;
- High income: GNI 12375; (in U.S. dollars per capita)

Data analysis
An aggregate of national data was the unit of analysis for statistics recorded in the ESC/EAPCI Atlas. Averaged data across the 35 participating countries are presented as medians with interquartile range (IQR) in parentheses. Non-parametric (permutation-based) correlation coefficient testing was used to test the significance of associations between two variables. The Pearson's correlation coefficient was calculated for log-transformed data and for 100 000 random permutations of the data to test the null hypothesis that variables were independent. We made no assumption of causation when associations were identified. Fisher-Pitman permutation tests was used to identify differences between income-level groups of countries. Paired Wilcoxon rank sum test was used for identifying differences between 2016 and 2018 data. Of note, p-values and the medians in 2016 vs 2018 data comparisons correspond only to those countries which participated in both surveys and were data are available (16 countries or less, depending on the variable).

Supplementary Appendix 2. Acknowledgements.

ESC National Cardiac Society of Interventional Cardiology or Working Groups of Interventional Cardiology: We acknowledge the national representatives of the corresponding interventional cardiology organisation for their contribution in collecting and developing the data.

Austria: Gudrun Lamm, Volker Muehlberger **Belarus:** Valeriy Stelmashok**,** Oleg Polonetsky **Belgium:** Walter Desmet **Bosnia & Herzegovina:** Ibrahim Terzic **Croatia:** Eduart Margetic, Kristina Maric Besic **Czech Republic:** Martin Mates **Denmark:** Karsten Tange Veien **Egypt:** Magdy Abdelhamid **Estonia:** Jaan Eha **Finland:** Tuomas Rissanen **France:** Philippe Commeau, Guillaume Cayla **Germany:** Holger Nef **Greece:** Skalidis Emmanouil **Hungary:** Zoltán Ruzsa **Israel:** Haim Danenberg **Italy:** Giuseppe Tarantini, Battistina Castiglioni **Kazakhstan:** Orazbek Sakhov **Latvia:** Arnis Laduss, Andrejs Erglis **Lithuania:** Ramūnas Unikas, Jelena Čelutkienė **Moldova:** Dumitru Tarita, Mihai Popovici, Ion Popovici **The Netherlands:** Michiel Voskuil, Dennis van Veghel **North Macedonia:** Elizabeta Srbinovska Kostovska, Jorgo Kostov, Sasko Kedev **Norway:** Christian Eek **Poland:** Wojtek Wojakowski, Zbigniew Siudak, Adam Witkowski **Portugal:** João Brum Silveira, Ana Domingues **Romania:** Lucian Predescu **Russia:** Evgeny Kretov **Slovakia:** Frantisek Kovar **Slovenia:** Matjaž Bunc **Spain:** Ana Belen Cid Alvarez, Armando Perez de Prado **Sweden:** Nils Witt **Switzerland:** Daniel Weilenmann **Türkiy**: Enver Atalar **Ukraine:** Yuriy Sokolov, Maksym Sokolov **United Kingdom:** Peter Ludman, Adrian Paul Banning

Supplementary Appendix 3. Infrastructure.

National infrastructure (See Supplementary Table 1)

The median number of hospitals with catheterization laboratories was 3.04 (IQR 2.12-4.29) per million people, ranging from 1.05 in Ukraine to 6.01 in Germany. Egypt recorded the largest increase, from 1.01 to 4.37 per million people (+353%) while Denmark recorded the largest decrease, from 2.27 to 1.90 per million people (-15%).

Human resource

In this survey, we found a median of 14.35 (IQR 9.93 to 19.81) interventional cardiologists per million people, ranging from 4.48 per million in Ukraine to around 30.37 per million in Turkey Egypt reported the strongest change since 2016 (+138%).

Catherization laboratories

The total number of catheterization laboratories ranged from 1.46 in Ukraine to 12.12 per million people in Germany, with a median across all countries of 4.87 (IQR 4.07-5.59) with data not available for Belgium, Israel, Netherlands. Similarly, Egypt recorded the largest rise (1.32 to 4.67 per million people, +268%) while Denmark recorded the largest decrease (5.41 to 4.66 per million people, -13%). High income countries have significantly higher number of catheterization laboratories compared to the middle income countries (5.24 vs 3.96, p=0.02).

A 24/7 service was provided by 59.7% of hospitals with catheterization laboratories [median 1.89 (IQR 1.17 to 2.91) per million people], ranging from 0.66 per million in Egypt and Denmark to approximately 4 per million in Belgium, Germany, Italy, and Poland (Table 1; data not available for Russia). Cardiac surgery was offered by 36.8% of hospitals with catheterization laboratories [median 1.02 (0.77 to 1.44) per million people], ranging from 0.27 per million in Ukraine to 3.73 per million in Turkey.

Switzerland and Italy have significantly larger number of hospitals with catheterization laboratories performing structural heart disease interventions, at 3.99 and 3.51 per million people compared to the median of 1.07 (IQR 0.69-1.51). There was also a significant difference between high and middle income countries (1.27 vs 0.63, p=0.008). There was a significant increase in hospitals with catheterization laboratories performing transcatheter aortic valve intervention (TAVI) with 0.86 in 2018 vs 0.78 in 2016, p<0.01 hospitals per million people, p<0.01.

Supplementary Figure 1 compares the Hospitals and Catheterization Laboratory numbers for middle and high income countries.

Supplementary Appendix 4. Procedures.
Illustrations in Supplementary Figure 2-Supplementary Figure 12.

Percutaneous Coronary Intervention (PCI)
A median of 2264.42 (IQR 1522.47 to 2696.69) PCI per million people were reported in 2018, ranging from <1000 in Moldova, Egypt, Ukraine and Belarus to >3000 in France, Switzerland, Latvia, Lithuania and Germany. There were no significant differences in the rate of PCI between 2016 and 2018 (2478.92 vs 2264.42, p=0.32) with France reporting the highest increase (+20%). Trans-radial access was used in >50% of cases in all countries except in Egypt and Turkey although both countries recorded large increase compared to 2016, (+30% and +17%, respectively). There was a significant correlation between rates of PCI and GNI per capita (r=0.69, p<0.001). Of note, stents were not implanted in over 20% PCI that were performed in Finland, drug-eluting stents were implanted in less than 60% of the cases where coronary stents were used in Russia. There has also been a large decrease in the average coronary bio-resorbable vascular scaffold use (1.18 in 2018 vs 10.76 in 2016, p=0.014).

Primary percutaneous coronary intervention (pPCI)
A median of 476.91 (IQR 377.54 to 602.84) cases of pPCI per million people were reported for 2018, although wide variation was noted with less than 200 cases per million people in Kazakhstan to >800 cases per million people in Turkey, North Macedonia and Lithuania. Of note, Turkey and North Macedonia are both middle income countries so there was weak positive correlation between pPCI and GNI. There was no significant difference in pPCI rates between 2016 and 2018 surveys (461.70 vs 476.91 p=0.73). However, Egypt and Poland recorded the highest changes, +471% and -21%, respectively. In Ukraine, pPCI accounted for >50% of PCI cases, which is significantly higher than average of the participating countries.

Intracoronary imaging and physiology guided PCI
The rates of PCI performed with adjunctive intracoronary imaging techniques [median 30.14 (IQR 7.49 to 120.33) per million people] ranged from 1.57 per million people in Ukraine to 158.33 per million people in Sweden (Figure S8; data not available for Austria, Czech Republic, Finland, France, Germany, Israel, Lithuania, Netherlands, Slovakia, Spain Switzerland). Similarly, there was a wide variation in the PCI performed with adjunctive intracoronary physiology measurements [median 20.42 (IQR 5.53 to 111.122) per million people] ranged from zero in North Macedonia to >300 per million people in Norway (Figure S12- data not available for Austria, Czech Republic, Finland, France, Germany, Hungary, Israel, Netherlands, Slovakia, Spain, Switzerland and Turkey). There was strong positive correlation for both adjunctive techniques (during PCI and coronary angiography) with GNI per capita [intracoronary imaging (r=0.87, p<0.001) and intracoronary physiology (r=0.88, p<0.001). There was also significant increase in the use of intracoronary physiology between the two surveys with 181.52 in 2016 vs 167.19 per million people in 2018, p=0.009 but no difference seen in the use of intracoronary imaging.

Adjunctive technologies
There was a wide variation in the use of rotational atherectomy with >70 per million people in France compared to the median of 16.16 (IQR 4.51 to 34.21) per million people. There was a reduction in the PCI with rotational atherectomy rates between the two surveys (median 16.2 in 2018 vs 25.5 per million people in 2016, p=0.057). Similarly, Italy, France and Switzerland

recorded >50 per million people use of haemodynamic support devices compared to middle income countries such as Egypt, Ukraine and Moldova with <10 per million people. However, there was no significant differences between the two surveys (median 12.08 in 2018 vs 15.88 per million people in 2016, p=0.426).

Supplementary Appendix 5. Structural interventional procedures.

Illustrations in Supplementary Figure 13-Supplementary Figure 15.

Transcatheter aortic valve implantation (TAVI)

An annual median of 51.73 (IQR 39.44-134.99) per million people were reported in 2018 with Germany leading with >250 TAVI implants per million people. All middle income countries implanted <50 TAVI per million people which resulted in strong positive correlation between TAVI implantation and GNI per capita ($r=0.95$, $p<0.001$). All countries, except Turkey and Greece reported increase in TAVI implantation in 2018 compared to 2016, with median 51.73 2018 vs 48.24 in 2016 per million people, $p<0.001$.

Percutaneous mitral procedures

Mitral valve percutaneous repairs were performed in a median 3.86 (IQR 0.06 to 9.89) per million people with Germany and Switzerland accounting for a large majority of the cases. There was no significant difference between the two surveys (median 1.46 in 2018 vs 1.86 per million people in 2016, $p=0.28$). The United Kingdom reported a small reduction in number of cases compared to 2016, but the remaining countries that participated in both surveys reported significant increase in procedural numbers ($p=0.007$). On the other hand, Turkey and Egypt, both middle income countries reported the largest number of mitral balloon valvuloplasty procedures in 2018.

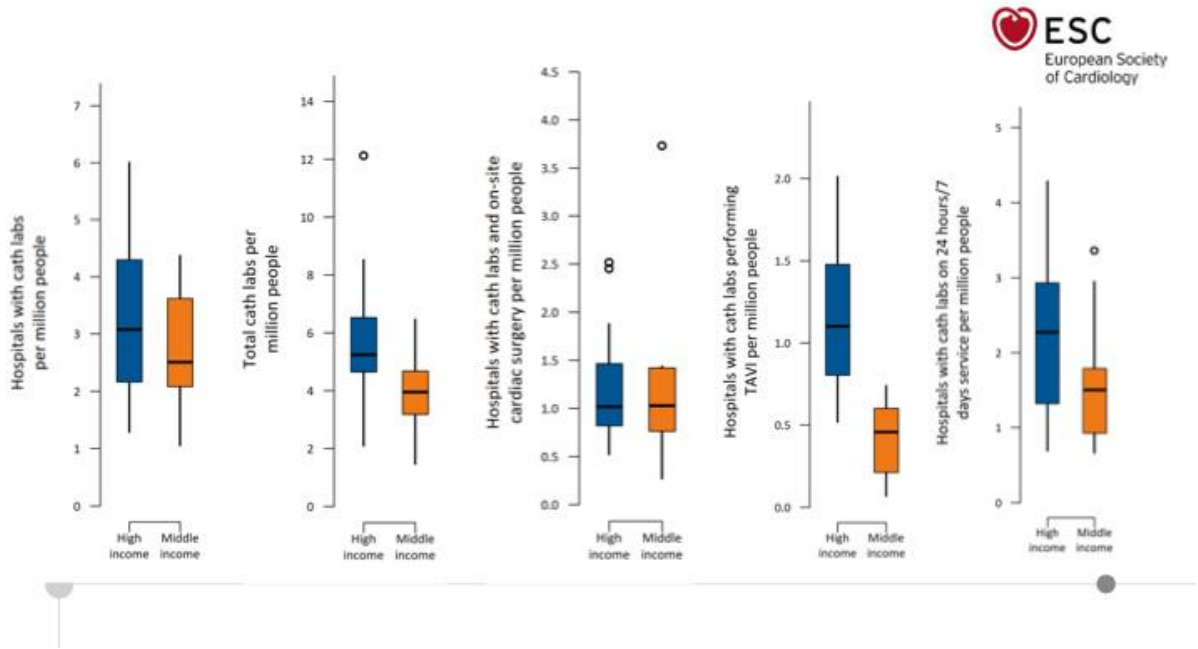
Other percutaneous interventional procedures

There was a wide variation in atrial septal closure procedure rates with Bosnia & Herzegovina reporting 2.4 while Germany reporting 65.2 cases per million people. A similar trend was observed in left atrial appendage occlusion and alcohol septal ablation procedures, where Germany recorded the highest number of cases among the participating countries, 64.2 and 6.0 cases per million people respectively. On the other hand, ventricular septal defect closure was most commonly performed in North Macedonia, 2.9 cases per million people with just data available from 18 participating countries.

Supplementary Table 1. Data collection policy.

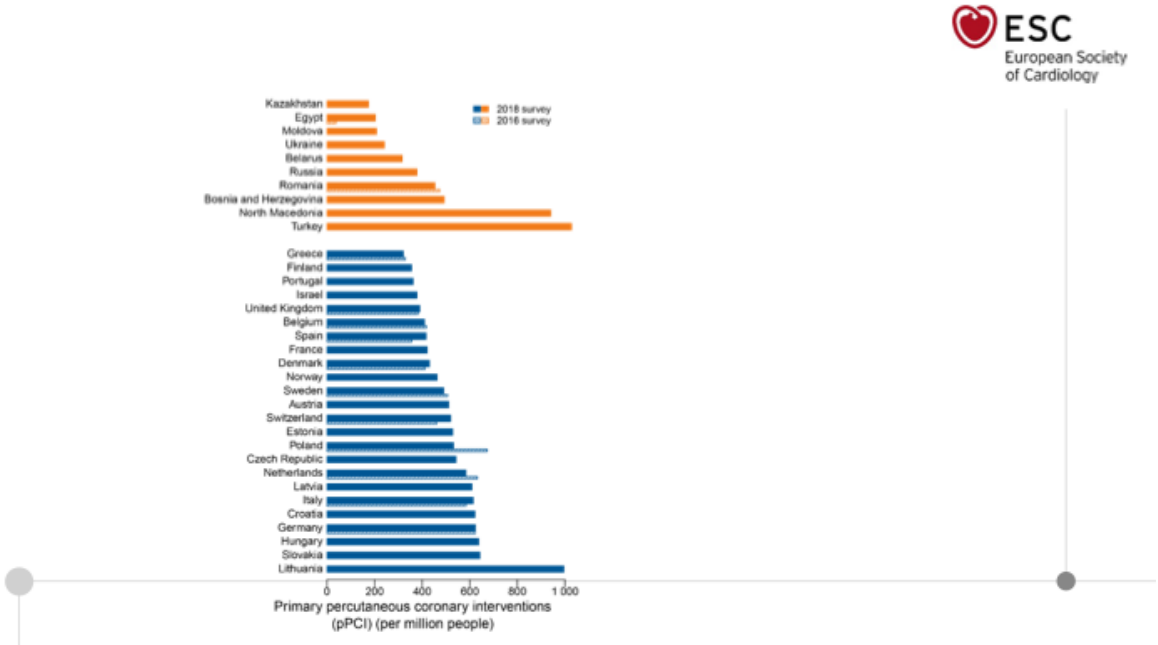
	Country	GNI per capita (USD)	Age-adjusted prevalence of ichaemic heart disease per 100 000 people	Age-Standardised CVD mortality per 100 000 people	Interventional cardiologists (per million people)	Total cath labs (per million people)	Hospitals with cath labs (per million people)	Hospitals with cath labs on 24 hours/7 days service (per million people)	Hospitals with cath labs and on-site cardiac surgery (per million people)	Hospitals with cath labs performing TAVI (per million people)	Hospitals with cath labs performing structural heart disease interventions in the adult (per million people)
lower Middle Income	*Egypt	2790	5626		10.16 (1.38)	4.67 (2.68)	4.37 (3.53)	0.66 (2.61)	0.76 (1.78)	0.12 (1)	0.2 (0.25)
	Ukraine	2800	4054		4.48	1.46	1.05	0.83	0.27	0.07	0.11
	Moldova	3930	3473		5.91	3.33	2.59	1.11	1.11	0.74	1.11
upper Middle Income	North Macedonia	5480	2846		21.12	5.28	4.32	3.36	1.44	0.48	1.44
	Belarus	5700	3616		16.34	4.01	2.74	1.79	0.95	0.21	0.42
	Bosnia and Herzegovina	5770	3059		7.52	4.21	2.11	1.5	1.2	0.6	0.6
	Kazakhstan	8070	3815		8.1	3.17	2.08	1.53	1.42	0.33	0.66
	Russia	10250	3573		13.7	3.9	2.44		0.76	0.44	0.45
	*Turkey	10520	3228		30.37 (0.55)	6.46 (0.41)	3.62 (0.05)	2.95	3.73 (0.08)	0.73 (0.71)	1.09
	*Romania	11430	2874		6.06 (0.39)	3.13 (0.24)	1.95 (0.09)	0.92	0.62 (-0.25)	0.56 (0.38)	0.77 (0.25)
High Income	Croatia	14080	2908		17.37	6.6	3.67	2.94	1.47	0.98	0.98
	* Poland	14150	2127		16.14 (0.07)	4.29	4.29 (0.01)	4.21 (0.01)	1 (0.00)	0.58 (0.05)	1.05 (0.05)
	Hungary	15020	3269		14.01	3.48	1.84	1.74	0.72		
	Latvia	16540	3606		16.09	5.19	2.59	1.04	0.52	0.52	0.52
	Lithuania	17460	3358		15.43	4.64	2.14	1.78	1.07	1.07	1.07
	Slovakia	18350	2752		9.36	2.09	1.29	1.29	0.55	0.55	1.1
	*Greece	18970	1631		21.24 (0.01)	6.52 (0.04)	4.94 (0.00)	2.52 (0.04)	2.52 (0.00)	1.49 (0.07)	1.68 (0.00)
	Czech Republic	20520	3404		13.17	4.7	2.16	2.07	1.32	1.32	1.6
	Estonia	21340	4312		11.35	5.3	3.78	2.27	1.51	1.51	1.51
	Portugal	22050	1329		9.53	4.18	2.72	2.33	1.17	1.56	1.85
	*Slovenia	24600	2860		20.25 (0.14)	5.3	4.34 (0.29)	0.96 (0.00)	1.45 (0.00)	1.45 (2)	1.45 (0.00)
	*Spain	29350	1689		9.89 (0.05)	5.11 (0.1)	2.33 (0.03)	1.99 (0.13)	1.43	1.32 (0.05)	1.77 (0.26)
	*Italy	33840	2033		17.26 (-0.03)	7.35 (0.00)	4.42 (0.00)	3.92 (0.01)	1.74 (0.00)	1.7 (0.11)	3.51 (0.08)
	Israel	40860	1649		19.36		3.04	2.48	1.46	1.46	1.46
	*France	41200	1621		14.35	5.03 (0.02)	3.08 (0.00)	3.08 (0.00)	0.82 (0.04)	0.82 (0.1)	1.27 (0.7)
	*United Kingdom	41770	1637		9.98 (0.00)	4.09 (-0.11)	1.78 (-0.33)	0.87 (-0.15)	0.68 (0.00)	0.62 (0.17)	0.62 (0.17)
	*Belgium	46100	1877		20.57 (-0.12)		4.29 (0.00)	4.29 (0.00)	2.45 (0.00)	2.01 (0.05)	2.36 (0.00)
	*Germany	47050	1993		28.59 (-0.45)	12.12 (0.03)	6.01	4.21	0.94 (0.00)	1.21 (0.11)	
	Finland	48280	1876		22.48	8.52	3.99	3.26	0.91	0.91	0.91
	Austria	49080	1787		30.31	6	3.73	1.13	1.02	1.13	1.58
	*Netherlands	51300	2258		10.97 (0.09)		4.29 (0.00)	1.8 (0.00)	0.93 (0.00)	0.93 (0.00)	0.93 (0.00)
	*Sweden	55580	1820		13.76 (0.02)	5.41 (0.1)	3.05 (0.03)	2.36 (0.2)	0.79 (0.00)	0.79 (0.00)	0.88 (0.12)
	*Denmark	61020	1761		15.53 (0.00)	4.66 (-0.13)	1.9 (-0.15)	0.69 (0.00)	0.69 (0.00)	0.69 (0.00)	0.69 (0.00)
	Norway	80640	1695		9.41	5.46	1.69	1.32	0.94	0.94	0.94
	*Switzerland	83730	1620		26.31 (-0.01)	6.93 (-0.02)	4.35 (-0.03)	2.82 (-0.2)	1.88 (0.07)	1.76 (-0.06)	3.99 (-0.11)

* *Countries which participated in the 2016 survey. Relative changes in comparison to 2016 data are shown in brackets.*

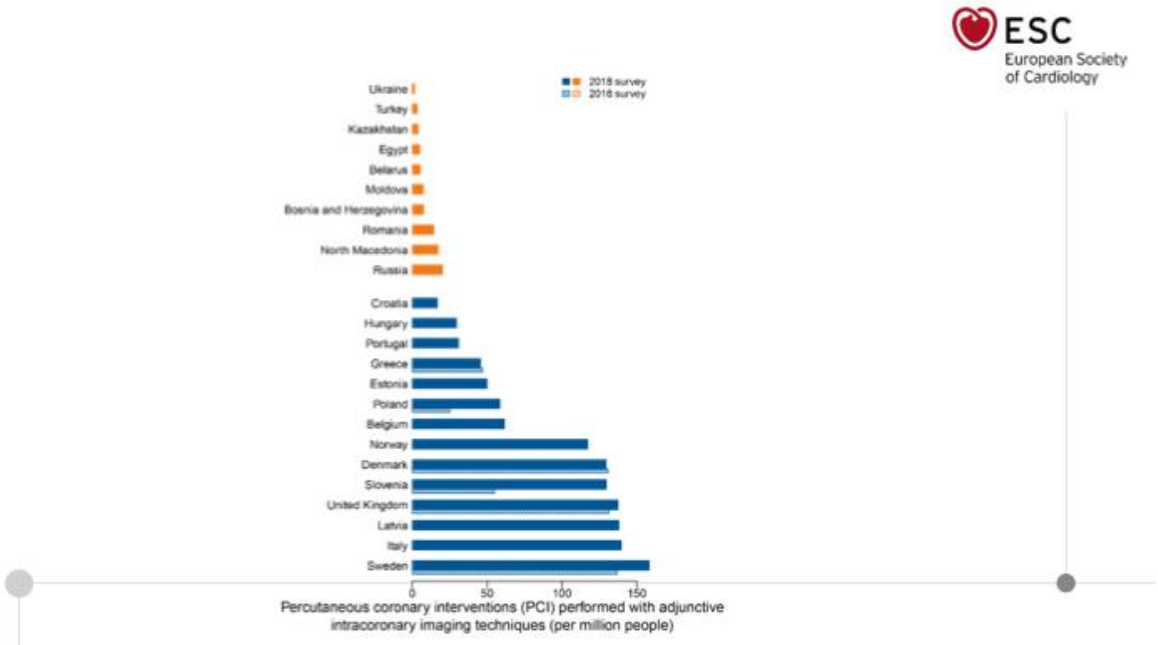


Supplementary Figure 1. Infrastructure and service: comparison of high- versus middle-income countries.

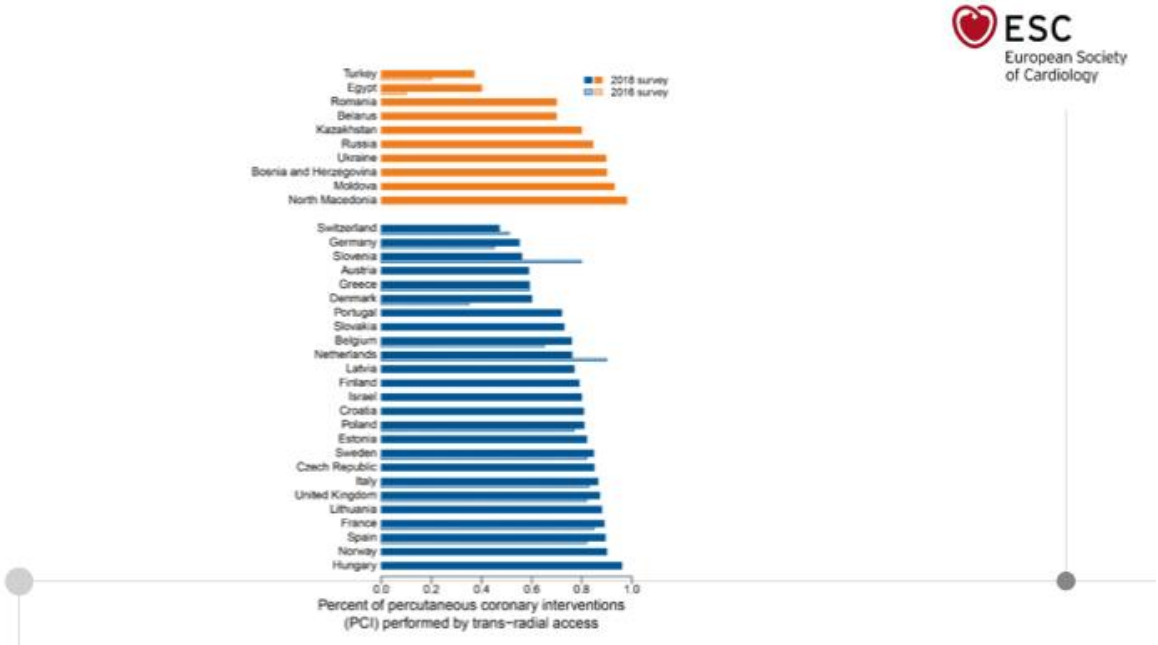
Supplementary Figure 2. Diagnostic procedures and PCI, 2016 and 2018.



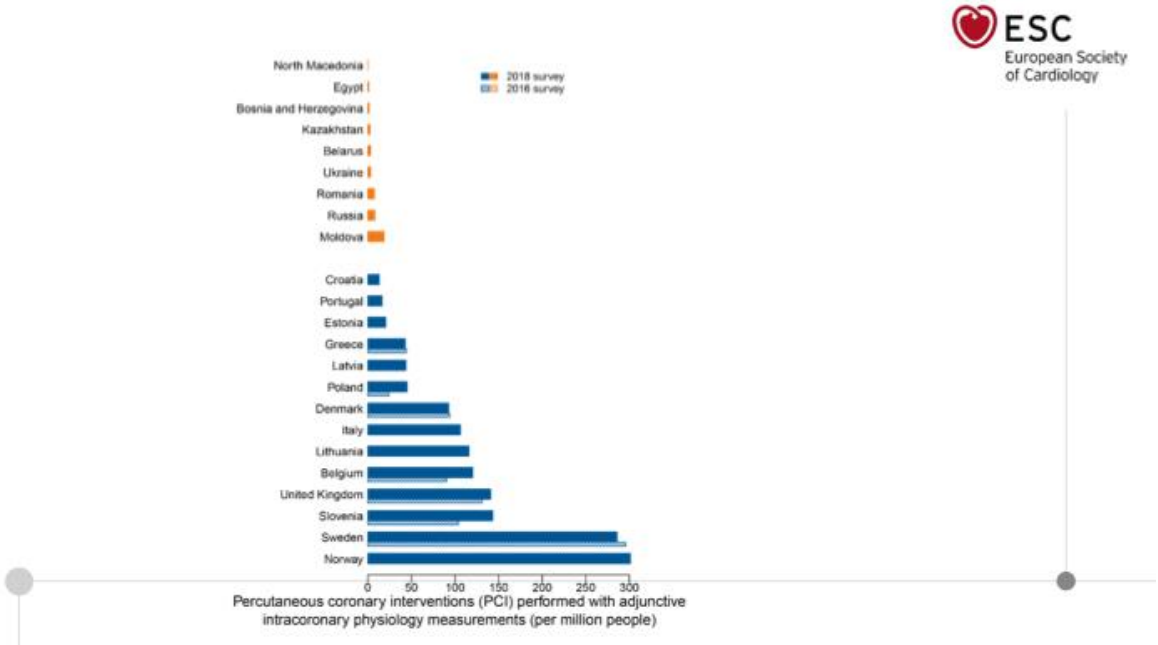
Supplementary Figure 3. Primary PCI, 2016 and 2018.



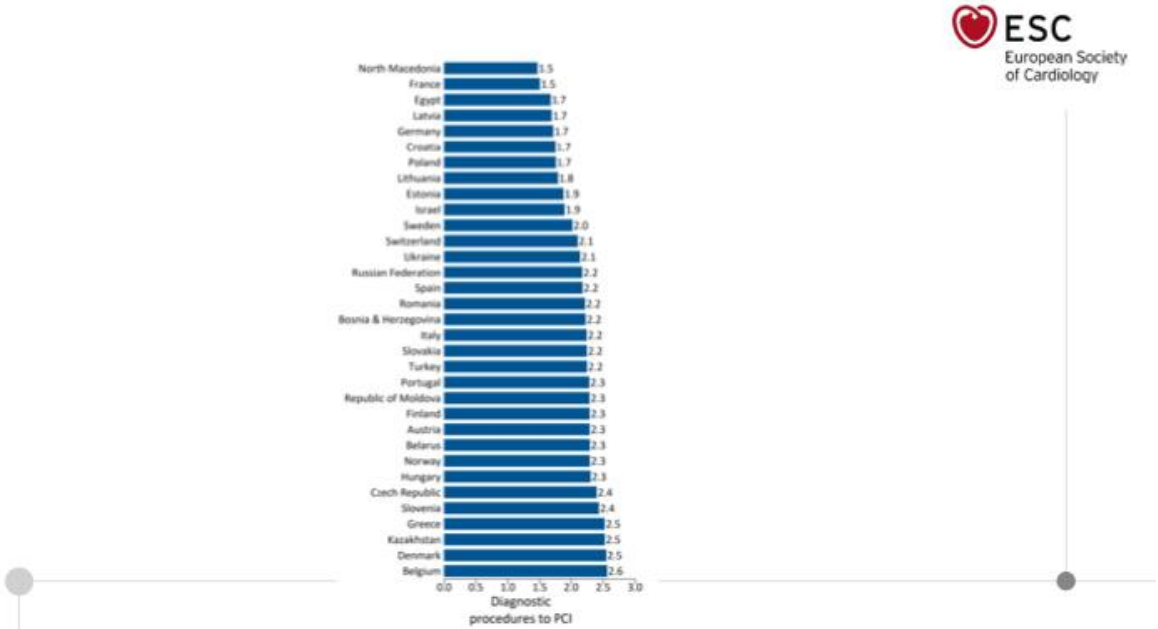
Supplementary Figure 4. PCI with adjunctive intracoronary imaging, 2016 and 2018.



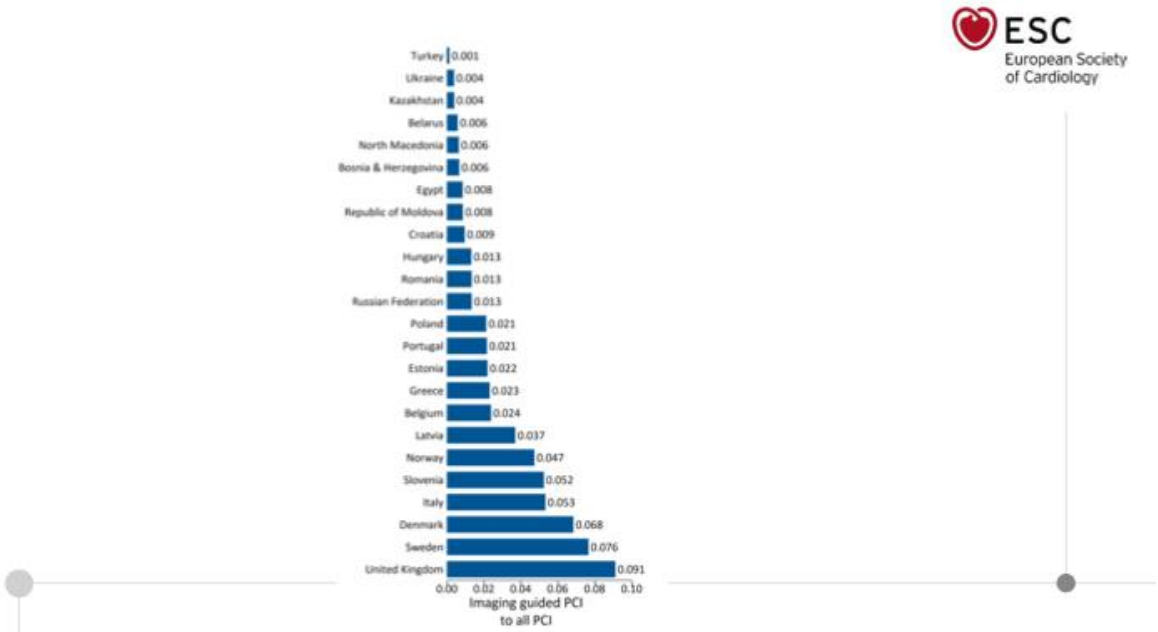
Supplementary Figure 5. Percentage of transradial PCI, 2016 and 2018.



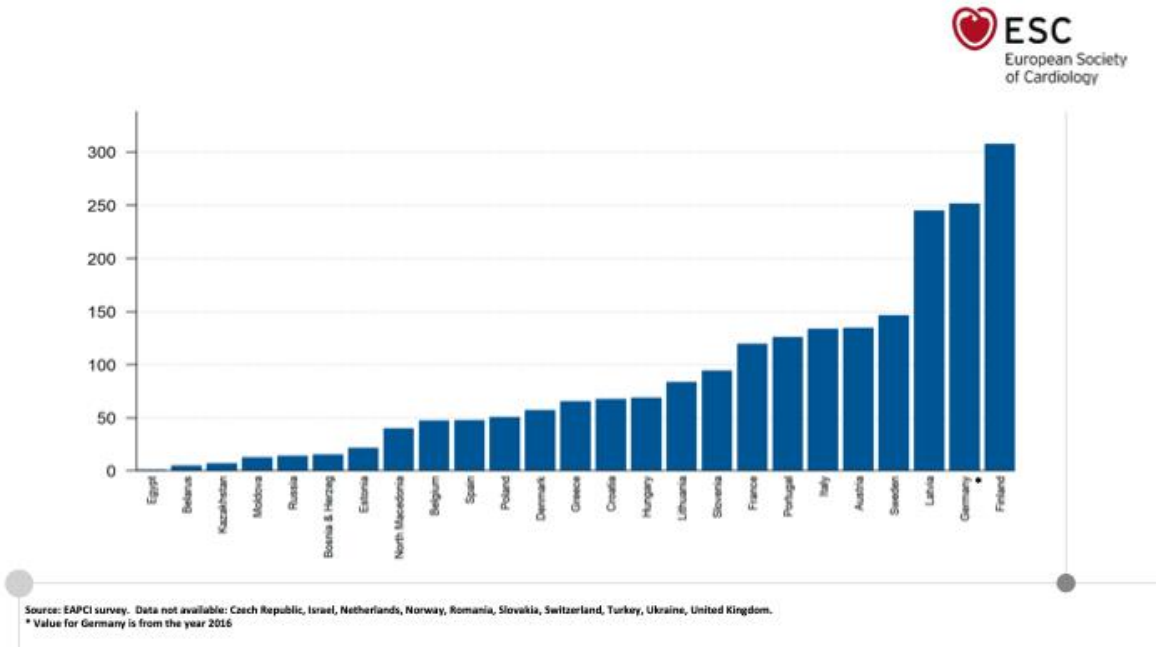
Supplementary Figure 6. PCI with intracoronary physiology measurements, 2016 and 2018.



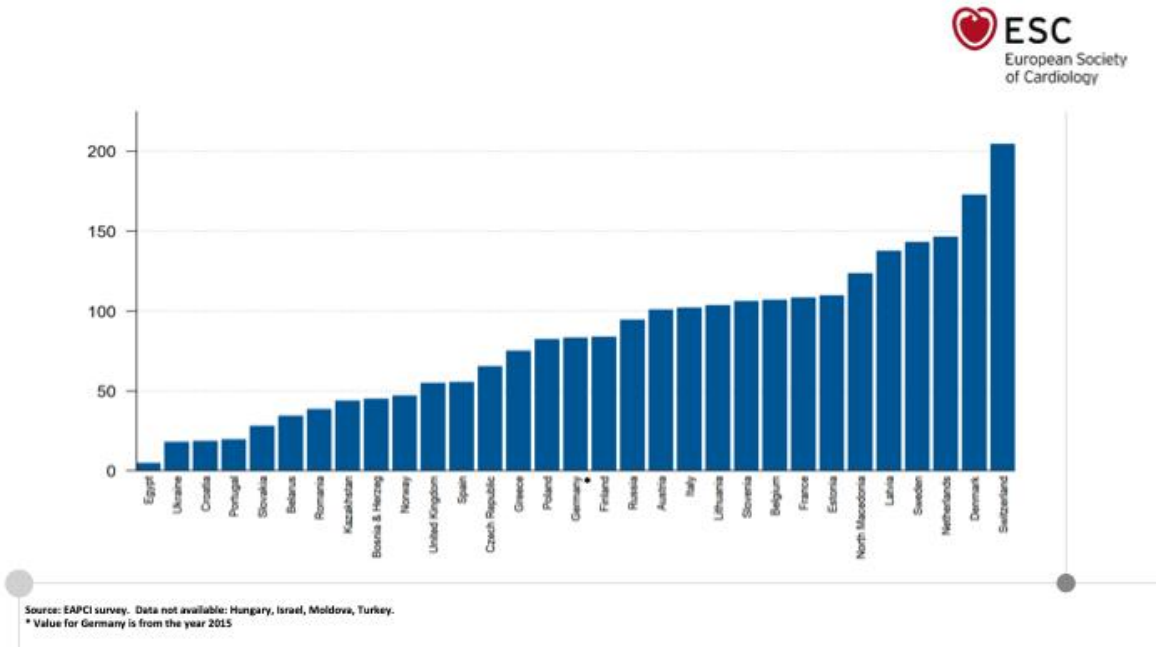
Supplementary Figure 7. Ratio of diagnostic procedures to PCI, 2018.



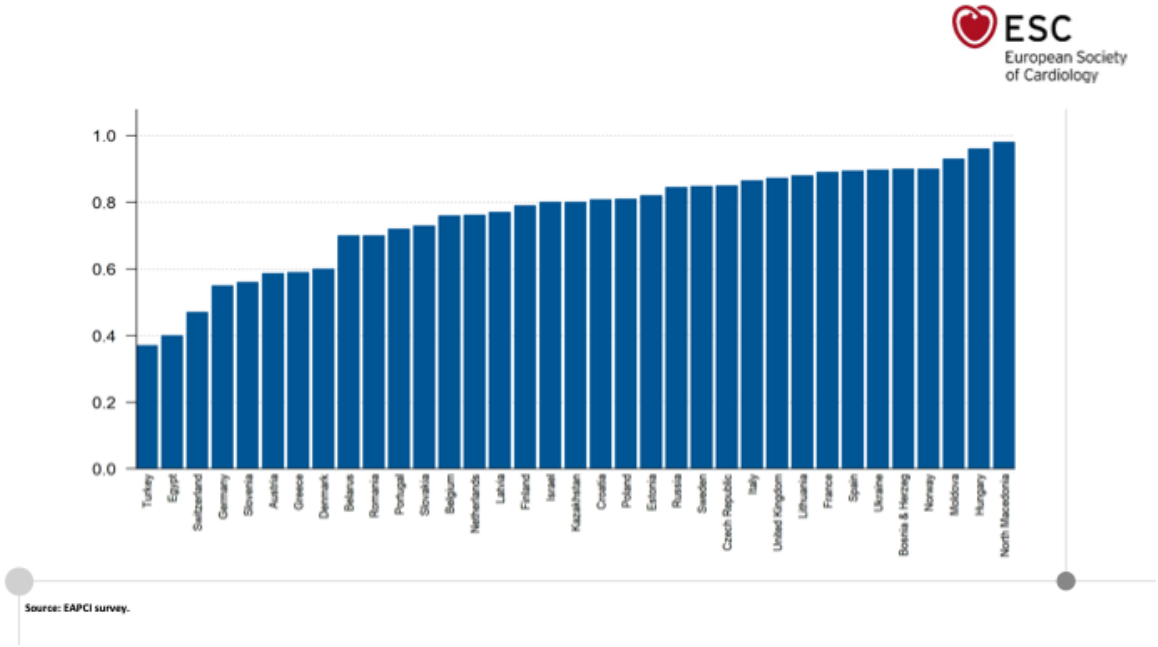
Supplementary Figure 8. Ratio of imaging-guided PCI to all PCI, 2018.



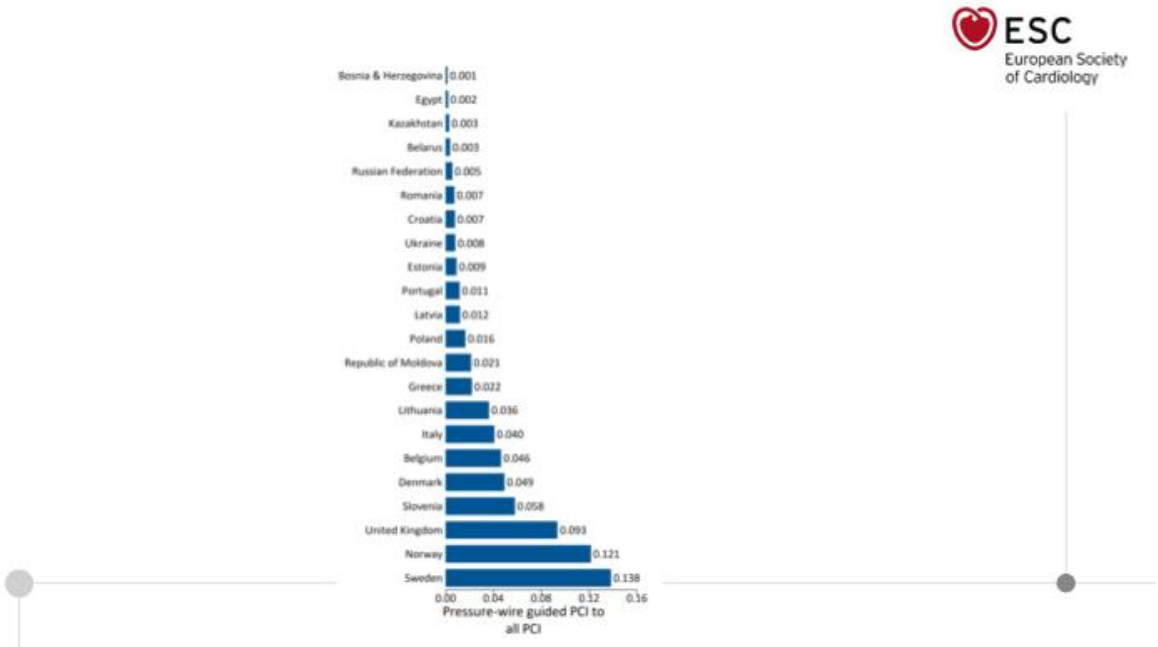
Supplementary Figure 9. PCI with drug-eluting balloons (per million people), 2018.



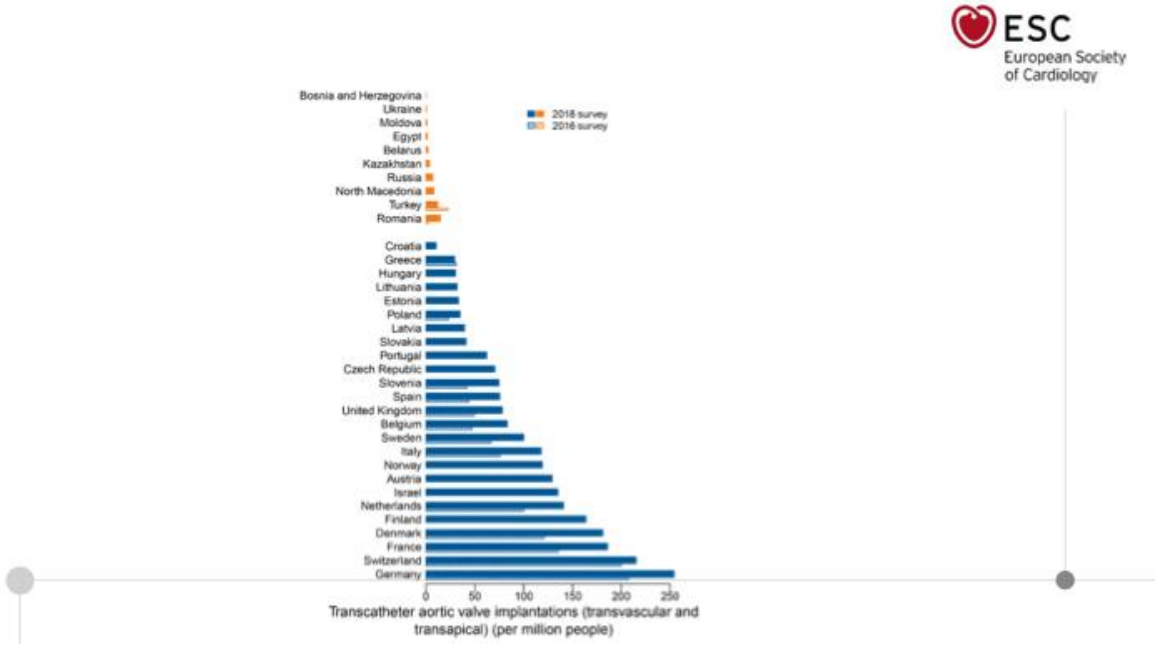
Supplementary Figure 10. PCI in coronary artery with chronic total occlusions (per million people), 2018.



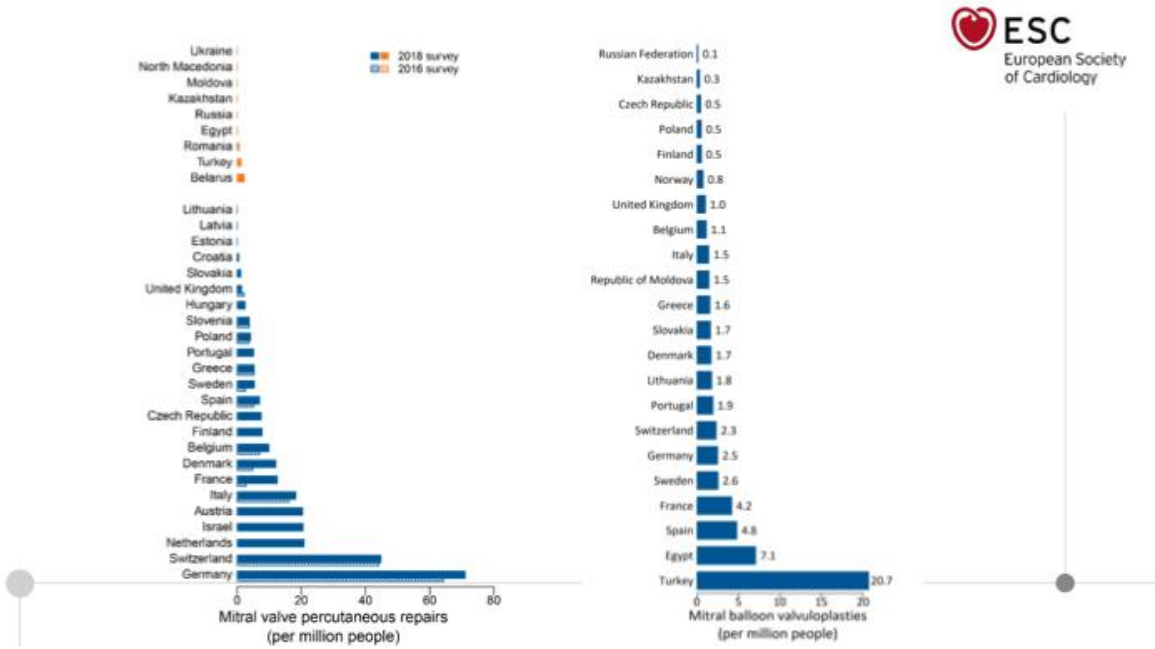
Supplementary Figure 11. Percentage of PC performed by transradial access, 2018.



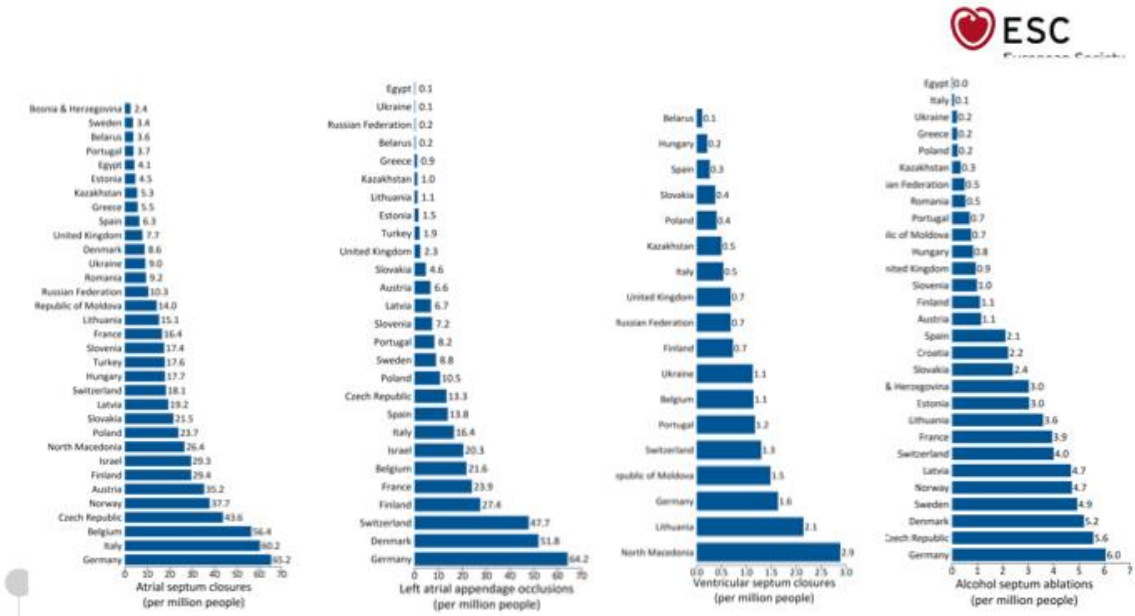
Supplementary Figure 12. Ratio of pressure wire-guided PCI to all PCI, 2018.



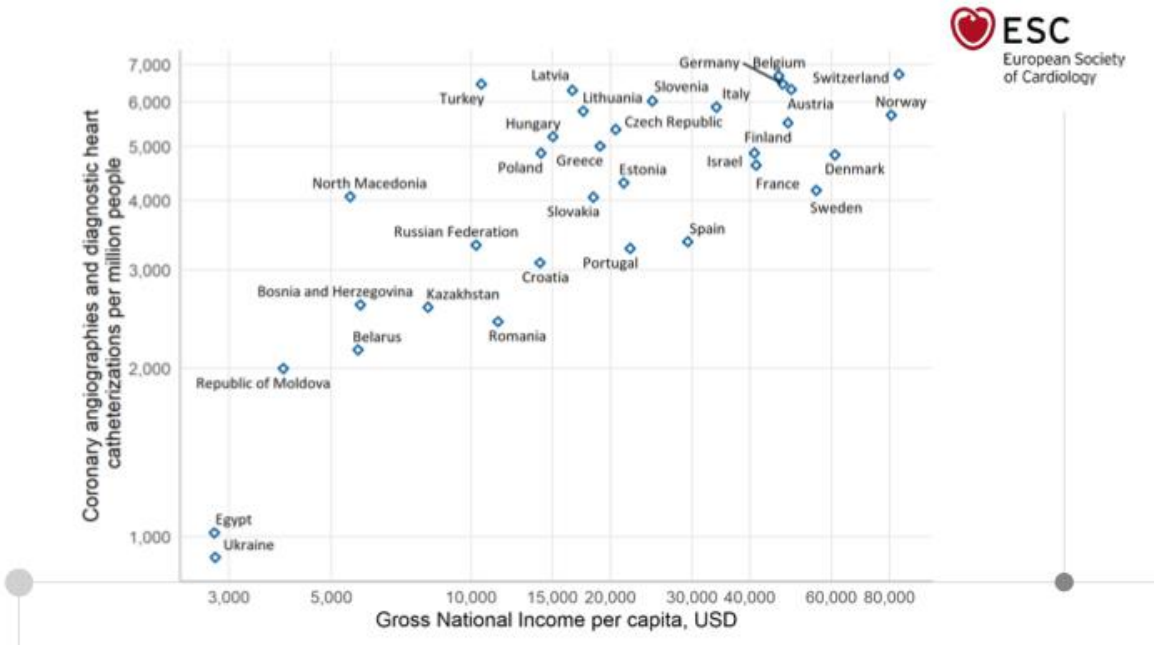
Supplementary Figure 13. TAVI, 2016 and 2018.



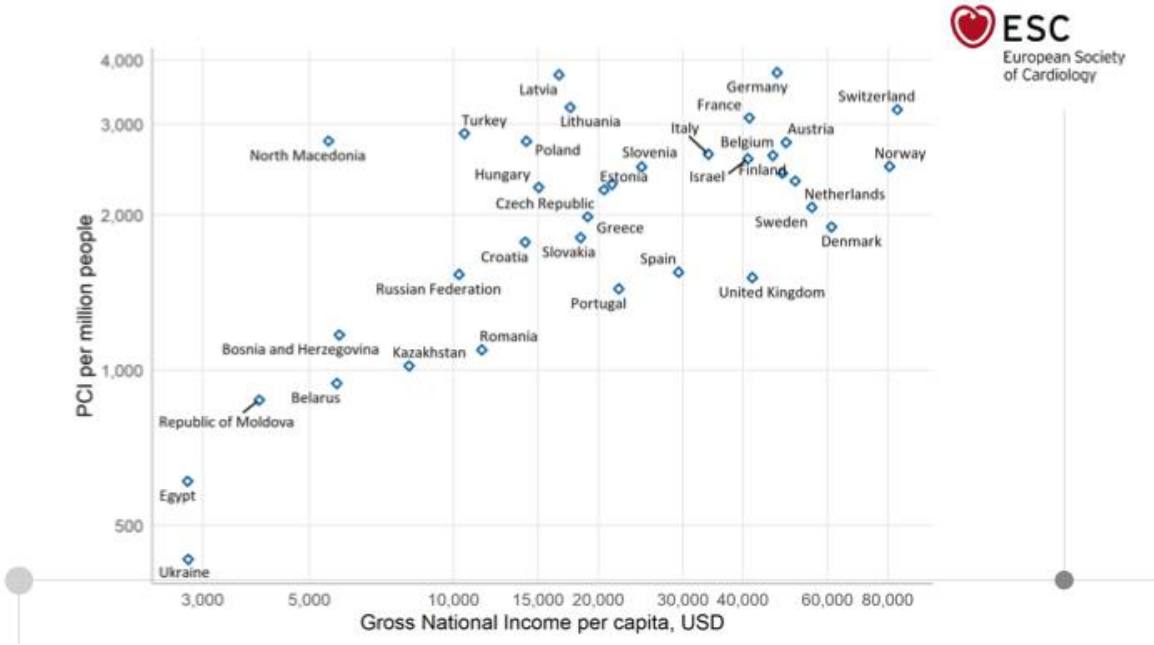
Supplementary Figure 14. Mitral valve percutaneous repairs and mitral balloon valvuloplasties, 2016 and 2018.



Supplementary Figure 15. Structural interventions: ASD, VSD, LAA and ASA, 2018.



Supplementary Figure 16. Diagnostic heart procedures versus GNI, 2018.



Supplementary Figure 17. PCI versus GNI, 2018.