Journal of Humanitarian Cardiovascular Medicine

Vol 1, No 3 (2024)

Current Publications

Current structure and needs of congenital heart surgery in Europe – a narrative review

Laszlo Kiraly, Zhi Xian Ong

doi: 10.12681/jhcvm.39886

To cite this article:

Kiraly, L., & Ong, Z. X. (2025). Current structure and needs of congenital heart surgery in Europe – a narrative review. *Journal of Humanitarian Cardiovascular Medicine*, *1*(3). https://doi.org/10.12681/jhcvm.39886

Journal of Humanitarian Cardiovascular Medicine

Current structure and needs of congenital heart surgery in Europe - a narrative review

Laszlo Kiraly, MD PhD FETCS[1,2,3], Zhi Xian ONG, MBBS[1]

[1]Department of Cardiac, Thoracic and Vascular Surgery, National University Heart Centre Singapore

[2]Department of Surgery, Yong Loo Lin School of Medicine, National University of Singapore

[3]Department of Public Health, Semmelweis University, Budapest, Hungary

Corresponding author
A/Prof Laszlo Kiraly MD PhD FETCS
Head, Department of Cardiac, Thoracic and Vascular Surgery, NUHCS
Senior Consultant, Paediatric Cardiac Surgery, Group Chief of Cardiothoracic Surgery, NUHS, Associate Professor, Department of Surgery, Yong Loo Lin School of Medicine, National University of Singapore, Associate Professor, Department of Public Health, Professor in Medicine (Hon), Semmelweis University, Budapest, Hungary
National University Hospital Singapore/National University Heart Centre Singapore (NUHCS)
1E Kent Ridge Road, NUHS Tower Block, Level 9, Singapore 119228
E-mail: kiraly_laszlo@nuhs.edu.sg, laszlokir@gmail.com
Tel: +65 8606 9324

Meeting presentation
The manuscript was online presented at the Global Forum for Congenital Cardiac Surgery, on 4 November 2024. Neither this work nor an abstract of this manuscript was submitted for the Global Humanitarian Forum biannual meeting.

Abstract

Background/Objectives: Congenital heart surgery is a relatively small discipline dealing with a circumscript patient population. The statement contrasts with the discipline's significant clinical impact for individual patients, and with the public health effect on the healthcare system. The aim of this narrative review is to survey the current landscape of congenital heart surgery in Europe, and especially to revisit the specific points of the recommendation document on the optimal center structure twenty years on.

Methods: European demographic patterns and prevalence/incidence of congenital heart disease were studied in national/international information resources. English-language literature of current congenital cardiac surgery practices, outcomes were reviewed. Recommendations on the optimal structure of a pediatric cardiac surgical department were specifically revisited.

Results: Europe is an ageing continent with stagnating birthrate. Promoters of congenital heart disease, e.g., consanguinity, segregated generative populations and lack of termination of pregnancy for fetal anomaly are absent. Congenital heart surgery has a long and successful history with world-renown centers of excellence. European professional organizations - joining forces with international counterparts - pioneer cooperation for establishing standards of quality-of-care, risk stratification and international databases. A review of the original recommendations for the optimal center and regional care structure show that statements on volume, quality are still valid; countries with higher socioeconomical index may have an abundance of centers that, in the pursuit of excellence to achieve the best possible outcomes, regionalization is advised. Owing to a much-improved survival, an increased adult population with operated congenital heart disease transits towards the adult services and requests specialized multidisciplinary teams to care for them.

Conclusions: Europe enjoys an advanced and accessible healthcare system for congenital heart disease. In fostering development, and focusing on quality-of-life rather than just a mere survival, a concentrated collaborative effort seems essential from the multidisciplinary team, researchers, and policymakers.

Keywords: Congenital heart disease, congenital heart surgery, pediatric, outcomes, quality care, healthcare organization.

Introduction

Congenital heart surgery (CHS) is a relatively small discipline dealing with a limited patient population that contrasts with its significant clinical impact for individual patients, as well as, a public health effect[1,2] on families and the healthcare system[3-5]. CHS has emancipated from cardiothoracic surgery and became a specialty on its own right[6]. It even expanded the name from 'pediatric' to 'congenital' heart surgery. Compared to adult cardiac surgery, where investments may be capitalized in the short term[7] - a patient who paid contributions is being operated on, recovers, and may return to the workforce in a short period of time -, congenital heart surgery may only expect its benefits to surface after many years[5,8]. CHS relies on multidisciplinary effort rather than surgical ego[9]. On a programmatic level, there is high threshold to meet as patient outcomes under public scrutiny[10,11]. There is a strong quantity/quality correlation where teams with high volume experience may avert complications to save improved outcomes[12]. As CHS remains a high-risk modality[13], comprehensive recommendation frameworks had been proposed for center setup, case-load and casemix, staffing[14] and key performance criteria[15]. The aim of this narrative review is to survey the current landscape of CHS in Europe and especially to revisit the specific points of the recommendation document[14] on the optimal structure twenty years on.

Materials and methods

Demographic patterns and prevalence/incidence of congenital heart disease in Europe was studied in national/international information sources. We also searched PubMed, Cochrane and Embase databases using key search words 'pediatric' and/or 'congenital cardiac surgery' and 'Europe'. Peer-reviewed articles including original articles, meta-analyses and systematic reviews that were in the English language were analyzed. Compilation of these articles yielded a volume of literature relevant to the understanding the current landscape of congenital cardiac surgery in Europe; that, as well as, the personal experience of the Authors constituted the material of this narrative review. Recommendations on the optimal structure for a congenital cardiac surgery department in Europe[14], published in 2003 were revisited.

Results

Socio-demographic trends in Europe

Europe is an ageing continent[16] affected by variable but altogether decreasing birthrate[17]. The current birth rate for Europe in 2024 is 9.805 births per 1000 people, a 0% increase from 2023. It is expected that European birthrate will stabilize at around 9.5 birth per 1000 people producing 0-0.1% population growth until the end of the 21th century[17]. Higher sociodemographic index, urbanization and education are the key factors that inversely affect infant mortality and fertility rate[18]. Europe traditionally excels in all these aspects and shares the experience of other countries, e.g., China[19] and Japan[20] where rapid development of the infrastructure, family planning policies and opening avenues in education for women resulted in a sharp decrease of birthrate and an ageing society.

Birth control strategies and termination of unintended pregnancies are widely available within Europe. Both unintended pregnancy and abortion rate fell in Europe by 54% and 64%, respectively, between periods of 1990-1994 and 2015-2019 (30y)[21]. Owing to multiple factors, e.g., improving social climate and infrastructural environment, better family planning and contraceptives, Eastern Europe witnessed the most dramatic drop of unintended pregnancies by 64% (v 5% in Western Europe) and abortions by 70% (v 1% in Western Europe). Nevertheless, overall termination rate remains high at 65.9% (Eastern Europe) and 38.1% (Western Europe)[21].

Prevalence and incidence of congenital heart disease (CHD)

Constant live-birth incidence of CHD is around 0.55-1.22%[22,23]. Factors[24] promoting a higher CHD prevalence, e.g., consanguinity[25], segregated or generally smaller generative subpopulations, and the lack of termination of pregnancy for fetal abnormality (TOPFA) are uncommon in Europe[26]. Population demographic studies found close correlation between consanguinity and prevalence of congenital heart disease[27-29].

Segregated and progressively inbreeding generative subpopulations show an increased CHD prevalence that was demonstrated among subsequent generations of immigrants[30]. The European Union (EU) allows freedom of movement within its borders. Internal migration among member states (1.5 million; 0.3% in 2021), immigration (1.5 million; 1.1% in 2021), and the 27.3 million (6.1%; 2023) non-EU citizens living in the EU produces multi-ethnicity and it possibly contributes to the mixing of the genetic pools and a larger generative population size[31].

Antenatal screening has become the standard in countries with higher socio-demographic index, especially in Europe[32]. Comparison of studies from Denmark[23] and Singapore[33] shows around 70% sensitivity and over 90% specificity for all CHDs, and 93% and 99% for the critical CHD, respectively. TOPFA for major CHD ranges from 57.8% (Denmark) to 92% (Singapore); the divergence could be attributed to socio-cultural values in South-East Asia, where family circumstances, financial burden of treatment, and expected competitiveness in society is a major factor towards TOPFA[33]. Antenatal screening appears to result in a 39% decrease in live-birth incidence of major CHD, and it definitely contributes to the transformation of CHD presentation pattern[23].

Outcomes of congenital heart surgery in Europe

First data (2002) from the European Congenital Heart Defects Surgery Database presented 30-days mortality rates of neonates: 17.94%, patients between 1-12 months: 6.41%, and beyond 12 months: 5.58%[34]. Recent (2024) outcomes of neonatal cardiac surgery show a significant improvement to 5.9% in 30-days mortality[35]. Nevertheless, neonatal cardiac surgery continues to pose a substantial challenge, particularly for neonates with functionally univentricular physiology and systemic obstruction; database 30-days mortality of modified Norwood-1 procedure is still at 16%[35]. A higher complexity in the average European CHS case-mix appears to correlate with multidisciplinary expertise, open access to professional services and on a broader scale with infrastructure, and advanced healthcare policies[36].

Structure of congenital heart surgery (CHS) in Europe

Based on the authors' personal experience in the professional community, current European CHS activity patterns accumulate into two patient clusters that represent the majority of the case-load. (1) neonates and young infants with high complexity and acuity are candidates for primary complete repair, and (2) on the other end, there is a growing population of adult-CHD (ACHD; grown-up congenital heart: GUCH) patients[3] and reoperations[2]. In between these focal groups, complete repairs and staged operations continue. **Figure 1.**

ACHD is a growing, often complex patient population that needs to be centralized, as they require cooperation of pediatric and adult mul-

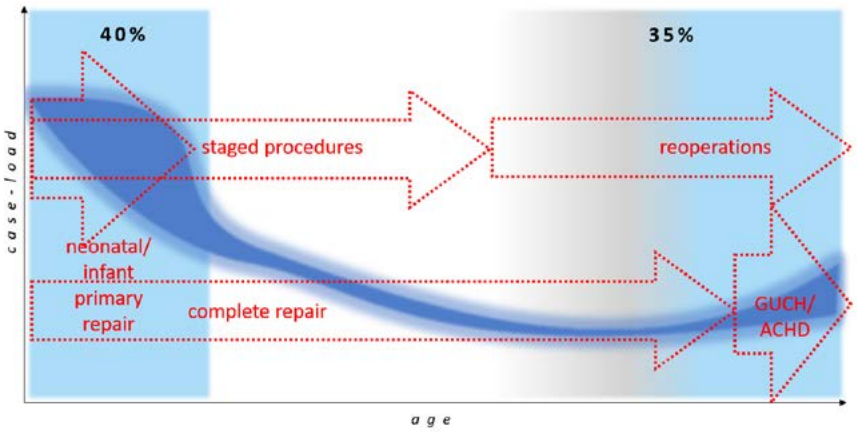

Figure 1. Contemporary CHS service patterns. Abbreviations: ACHD: adult congenital heart disease, GUCH: grown-up congenital heart (disease).

tidisciplinary teams (MDT), and sometimes an input from non-medical professionals, too[3,8,37]. Most European centers have already set up comprehensive ACHD services[37].

Daenen et al. published recommendations for the optimal structure of a congenital heart surgery department in Europe in 2003[14]. This seminal document advised about a minimal overall center activity (250 patients operated per year), case-mix and complexity (at least 100 neonates and infants operated per year; availability of ACHD, and concentration of transplantation into specialized centers). Surgical manpower was stipulated as at least two fully trained surgeons individually performing 125 procedures per annum. A personalized, i.e., patient-centered approach (surgery vs. interventional procedure) for every complex anomaly was proposed in the form of MDT discussion and agreement. The document also formulated estimations about the need for CHS in European countries based on population demographic data. Twenty years onwards, we have updated the demographic statistics and estimations applying the original methodology. **Table 1.** presents the updated and

Table 1. European population and birth rate, estimated CHS need and estimated CHS center activity

Country	Population (million)a	Birthrate (1/104pop)b	Births (2023)b	CHS need (0.4% of births)c	Center (No)d	New patient/ Center/year	130% (staged-reops)
Albania	2.791	1.23	34329	137	1	137	178
Austria	9.12	0.93	84816	339	4	85	111
Belgium	11.738	1.08	126770	507	6	85	111
Bosnia	3.164	0.82	25945	104	1	104	135
Bulgaria	6.757	0.79	53380	214	1	214	278
Croatia	3.875	0.85	32938	132	1	132	172
Czech Republic	10.735	0.98	105203	421	1	421	547
Denmark	5.977	1.13	67540	270	1	270	351
Finland	5.617	1.02	57293	229	1	229	298
France	66.548	1.09	725373	2901	15	193	251
Germany	84.552	0.89	752513	3010	31	97	126
Greece	10.047	0.74	74348	297	2	149	194
Hungary	9.676	0.91	88052	352	1	352	458
Ireland	5.255	1.11	58331	233	1	233	303
Italy	59.342	0.71	421328	1685	22	77	100
Latvia	1.871	0.83	15529	62	1	62	81
Lithuania	2.859	0.89	25445	102	1	102	133
Moldova	3.034	0.84	25486	102	1	102	133
Netherlands	18.228	1.06	193217	773	4	193	251
Norway	5.576	1.04	57990	232	2	116	151
Poland	38.539	0.84	323728	1295	28	46	60
Portugal	10.425	0.8	83400	334	3	111	144
Romania	19.015	0.85	161628	647	4	162	211
Russia	140.82	0.84	1182888	4732	10	473	615
Serbia Montenegro	7.355	1.09	79570	318	2	159	207
Slovakia	5.505	1	55050	220	1	220	286
Slovenia	2.118	0.8	16944	68	1	68	88
Spain	47.91	0.71	340161	1361	15	91	118
Sweden	10.606	1.07	113484	454	2	227	295
Switzerland	8.921	1.01	90102	360	5	72	94
Ukraine	35.661	0.6	213966	856	3	285	371
United Kingdom	69.138	1.08	746690	2987	12	249	324

Adapted and updated from *Daenen et al.*[14]. **Methodology notes:** not all reporting centers are full CHS programs; not all CHS centers report to ECHSA Database; no data are available on individual centers' case-mix, caseload, characteristics, and regional roles. **Information sources**: [a] Population demographic data in Europe 2024[39]. [b] Population demographic data in Europe 2024[40]. [c] UK Cardiothoracic Surgery. SAC and SCTS Workforce report 2019 [6]. [d] Centers registered at the European Congenital Heart Surgeons Association Database[38].

presumed surgical output of centers registered at the European Congenital Heart Surgeons' Association (ECHSA) Database in 2024[38].

It is readily admitted that our extrapolations suffer from possible methodological flaws as not all reporting centers may be full CHS programs; not all CHS centers report to ECHSA Database, and no information is available on individual centers' case-mix, caseload, characteristics, and regional roles; assumptions presented herein only serve as an illustration about CHS landscape in Europe. Furthermore, 'CHS need' column only estimates the annual volume of new CHD patients requiring CHS so, in wanting to estimate a more realistic workload of the program, an additional column was added to tabulate 30% additional surgical volume[2] of staged operations, reoperation ('130%' column). A review of the original recommendations for the optimal center and regional care structure show that European countries provide adequate coverage for CHD/CHS. Countries with higher socioeconomical index - and/or located closer to the ECHSA Database - seem to have an abundance of centers.

Discussion

Europe is an ever-changing continent of too many, too small countries with wide a variety of traditions and languages[16]. The European Union that now conjoins 60% of Europe's population started as an economic project, based on the freedom of movement of goods, services, people, capital, and data, the artery of the modern economy. However, healthcare remains in the hands of individual member countries[41]. Likewise, the congenital cardiac domain is ever changing, and a 'project' once started as a transatlantic cooperation[42] has become worldwide profession[43]. However, our profession is rather small in comparison to adult cardiothoracic surgery, let alone adult cardiology, and it is somewhat fragmented by its essentially multidisciplinary nature[8,9]. Given the high acuity and often high complexity of our work, there are cognitive blind spots[12]. Therefore, teamwork, open communication is a must, despite *'marrying teamwork to your own ego is quite difficult at times - and now, we're still learning that'* (WJ Brawn)[9].

Europe has always been a driver for development in congenital cardiac care and surgery[4]. The following observations and recommendations may contribute to ensure high-quality care and serve to preserve the esteemed status:

Equitable access to specialized care. There are regional disparities in access to congenital cardiac surgery across Europe, with some countries/regions having a high-density of specialized centers. **Figure 2.** is a graphic representation

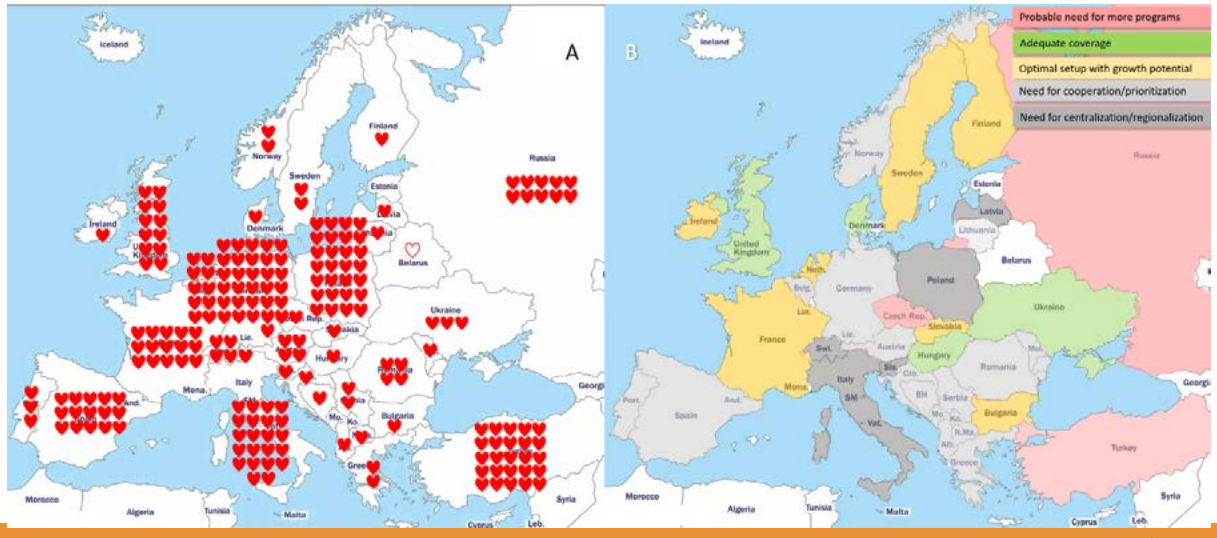

Figure 2. A: Graphic representation of European congenital cardiac centers reporting to the ECHSA Database[40]. B: Presumed country performance based on a minimal center requirement of 250 operations per annum. Methodical limitation: not all reporting centers are full CHS programs; not all CHS centers report to ECHSA Database; no data are available on individual centers' case-mix, caseload, characteristics, and regional roles.

of centers in the ECHSA Database on Europe's map.

Distribution of services may seem unequal in Europe, but overall, it is adequate. Countries with higher socioeconomic index appear with an abundance that results from local traditions, existing infrastructure and knowledge, politics and culture. Combined realization of accessible care, the best possible outcomes and a (financially) sustainable system is demanded by the public, regulator, and the financier.

Higher volumes - where experience ameliorates earlier detection and rescue complications[12] - theoretically offer the best possible outcomes. In pursuing excellence, regionalization is advised for centers with less than 75 operations/year; prioritization between 75-150 operations/year. Centers with an annual output between 150-250 could grow with regional cooperation. Traditionally, smaller programs are divisions of a cardiothoracic surgery department; middle-sized services are situated in children hospital and large supercenters (with a surgical output more than 500 operations per annum) constitute standalone congenital cardiac institutes. Supercenters typically embrace strong research and education faculties and they assume roles in professional policy-making on an international level.

Establishing efficient referral systems and centralization of services into larger centers has been repeatedly attempted[44-47]. Regionalization instead of a mere centralization should be based on professional agreement, e.g., experience sharing and funneling patients towards regional/comprehensive centers in the pursuit for excellence. Thus, networks should be created that maximize expertise, diminish duplication, minimize impact on access and variation and cut costs. **Table 2.** proposes a cooperation scheme between comprehensive, regional and essential centers in CHS based on the original principles[14].

It is preferred that organic development of comprehensive centers is initiated by local (professional, patient/family, public) forces based on existing infrastructure/knowledge, traditions, culture. Experts on healthcare inequities, and healthcare leadership contribute with financial structure considerations, and arbitration. By applying a balanced, practical approach, reduced access to care should be avoided. CHS regionalization is not for benefitting few/large centers, but for promoting excellence and providing the best possible outcomes[48].

Training the next generations of congenital cardiac surgeons. Medicine in general, and congenital cardiac surgery in particular, nowadays, may not attract the best candidates for the long training period, increased responsibilities, non-proportional remuneration packages, and work-life imbalance[49,50]. Limited career opportunities coupled with elevated public expectations on performance and outcomes, and the steep learning curve complicate CHS training in this narrower super-specialty[10]. CHS, thus, remains a vocational career path[43]. Individual and team mentoring, education of trainees at high-volume, high-quality centers, and provisions of continuing coaching appears to be a successful avenue that is increasingly applied[51]. A number of European CHS centers are recognized as world-leading

Table 2. Characteristics of proposed congenital cardiac comprehensive, regional centers and essential centers

Care delivery	General principles 2003(14)	Comprehensive center	Essential center
Volume	Over 250 patients operated/year	250+	150+
Case-mix, complexity	Neonatal and infant surgery: over 100/year Specialist MDT for complex ACHD Heart and/or heart-lung transplantation at dedicated centers	Full spectrum of complexities and modalities	Ceiling for complexity Neonatal, transplant activity only in collaboration with comprehensive center
Accessibility	24/7	24/7	24/7
Manpower (surgical)	at least two fully trained surgeons; minimum 125 operations/operator/year	3+	2+: minimum 75 operations/operator/year
Setup	Individualized approach (surgery vs. interventional procedure): every complex anomaly discussed at MDT meeting	Individualized approach (surgery vs. interventional procedure): every complex anomaly discussed at MDT meeting	

education programs offering fellowship opportunities, and attracting trainees from all over the world.

Standardized protocols, continuity-of-care principles can help standardize care through a comprehensive clinical quality assurance program that monitor outcomes. Working groups from the European Society for Cardiothoracic Surgery (EACTS) and ECHSA as well as the Society of Thoracic Surgeons (STS) created a conjoint terminology system, established a risk stratification system, key performance indicators and their respective Congenital Heart Surgery Databases[52]. Convergence of the existing national and European registries for congenital heart disease would help track outcomes and could launch long-term care strategies. Subscription and adherence to the guidelines of one of the international registries is now a criterion of CHS center recognition[14]. CHS, dealing with a well-defined patient population, employing transparent and measurable methods naturally offers itself for systematic standardization.

Research and innovation have always been a core signifier of CHS in Europe. The segmental approach in cardiac morphology - championed by *Professor RH Anderson* and the *Leiden school* - is one of the celebrated achievements of European academic research contributed to the world. Increased funding for research initiatives focused on congenital heart defects can lead to innovative surgical techniques and better perioperative care strategies[10,37]. Professional organizations e.g., ECHSA and EACTS establishing networks, pioneer multicentric projects across countries or even continents can facilitate large-scale studies and the sharing of the best practices[36].

Sadly, CHS's market share is low, thus research and innovation does not attract the financial incentives for the healthcare industry. Despite significant efforts and advances, availability of a living and growing bioprosthesis remains unresolved[53]. This Holy Grail of CHS holds a promise of significant public health impact/benefit as it could profoundly change the outlook of many patients by avoiding repeated reoperations[2]. As new modalities transpire from adult cardiothoracic surgery, CHS is now armored with hybrid[54], endoscopic[55], robotic[56] techniques, although they did not fully distribute into the specialty[57].

As mentioned, CHS is a multidisciplinary effort, however, it extends beyond the clinical team. It involves patient/family support groups, social services and online information resources, educational websites, etc. Providing clear information and resources to families about their child's condition and treatment options can alleviate stress and improve understanding as well as adherence. This is especially crucial with **transition programs** when pediatric patients change over to adult care, as many of them will require ongoing management into adulthood[3-5,8,37]. Multidisciplinary care teams consisting of cardiologists, surgeons, nurses, nutritionists, and psychologists can provide holistic care for patients and their families[5]. They also form personal connections, build trust. Since Europeans are less prevalent to frequently change residence than e.g., Americans, one may find shining examples for long-term follow-up: *'caring for congenital heart disease is a lifelong commitment'*.

Funding and Resources. Most European countries provide tax-based and/or health insurance through payroll taxes national health services in which access to CHS coverage is a statutory right[39,41]. In the light of spiraling healthcare costs, advocacy for increased funding from governments and private organizations can enhance resources available for pediatric cardiac care. Investing in the latest surgical technologies, imaging techniques, and postoperative care equipment is necessary for improving surgical outcomes[57].

Limitations of the study

This review is a snapshot in time and is limited to selected aspects of CHS in Europe. Authors did not have direct access to ECHSA Database.

Conclusion

Europe enjoys an advanced and accessible healthcare system for congenital heart disease. In focusing on quality-of-life rather than just a mere survival, a concentrated collaborative effort seems essential from the multidisciplinary team,

researchers, and policymakers. The profession (CHS) as a modality and practice is heterogeneous, its organization evolving. Its progress happens in front of the colorful socio-economic-demographic landscape of Europe. This landscape thrives on deep cultural roots, intellectual achievements, current economic and political turmoil. Despite the traditional fragmentation, Europe has always had the potential to unite and rejuvenate as the Welsh poet, *Sheenagh Pugh* put it[58]:

Sometimes things don't go after all,
From bad to worse. Some years, muscadel
Faces down the frost. Green thrives. The crops don't fail,
Sometimes a man aims high, and all goes well.
(from Sometimes)

Acknowledgement

This work was online presented at the Global Forum for Congenital Cardiac Surgery, on 4 November 2024. Neither this work nor an abstract of this manuscript was submitted for the Global Humanitarian Forum biannual meeting.

Institutional Review Board Statement: Ethical review and approval were waived for this study for it reviews describes well established and accustomed surgical techniques and policies, published in relevant literature, and for the fact that the current study does not involve humans or animals.

Funding statement

This work received no external funding.

Conflict of interest: none declared.

References

1. Pardhan S, Mandalenakis Z, Giang KW, Fedchenko M, Eriksson P, Dellborg M. Healthcare consumption in congenital heart disease: A temporal life-course perspective following pediatric cases to adulthood, Int J Cardiol Cong Heart Dis 2023;11:100440. https://doi.org/10.1016/j.ijchd.2023.100440.
2. Jacobs JP, Mavroudis C, Quintessenza JA, Chai PJ, Pasquali SK, Hill KD, Vricella LA, Jacobs ML, Dearani JA, Cameron D. Reoperations for pediatric and congenital heart disease: an analysis of the Society of Thoracic Surgeons (STS) congenital heart surgery database. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu 2014;17:2-8. doi: 10.1053/j.pcsu.2014.01.006.
3. Webb G. Grown-up congenital heart (GUCH) disease: Current needs and provision of service for adolescents and adults with congenital heart disease in the UK. Heart 2002;88(Suppl1):i1-i14.
4. GBD 2017 Congenital Heart Disease Collaborators. Global, regional, and national burden of congenital heart disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017 [published correction appears in Lancet Child Adolesc Health. 2020 Feb 7]. Lancet Child Adolesc Health 2020;4:185-200. doi:10.1016/S2352-4642(19)30402-X.
5. Rossano JW. Congenital heart disease: a global public health concern. Lancet Child Adolesc Health 2020;4:168-169. doi: 10.1016/S2352-4642(19)30429-8.
6. UK Cardiothoracic Surgery. SAC and SCTS Workforce report 2019. https://scts.org/wp-content/uploads/2019/01/SCTS-workforce-report-2019.pdf. Accessed on 16 August 2021.
7. Obafemi T, Mullis D, Bajaj S, Krishna P, Boyd J. Results following implementation of a cardiac surgery ERAS protocol. PLoS One 2023;18:e0277868. doi: 10.1371/journal.pone.0277868.
8. Marelli AJ, Ionescu-Ittu R, Mackie AS, Guo L, Dendukuri N, KaouacheM. Lifetime prevalence of congenital heart disease in the general population from 2000 to 2010. Circulation 2014;130:749-756.
9. Giants of Cardiothoracic Surgery: An interview with William J Brawn. CTSNet Video, 2 Mar 2017. https://www.youtube.com/watch?v=eMgVoL748uI.
10. Monro JL. Lessons to be learnt from the Bristol affair. Ann Thorac Surg 2000;69:674-5. doi: 10.1016/s0003-4975(00)01089-4. PMID: 10750741.
11. Bakaeen FG, Svensson LG, Mitchell JD, Keshavjee S, Patterson GA, Weisel RD. The American Association for Thoracic Surgery/Society of Thoracic Surgeons position statement on developing clinical practice documents. J Thorac Cardiovasc Surg 2017;153:999-1005. doi: 10.1016/j.jtcvs.2017.01.003.
12. Gonzalez AA, Dimick JB, Birkmeyer JD, Ghaferi AA. Understanding the volume-outcome effect in cardiovascular surgery: the role of failure to rescue. JAMA Surg 2014;149:119-23. doi: 10.1001/jamasurg.2013.3649.
13. Coulson JD, Seddon MR, Readdy WF. Advancing Safety in Pediatric Cardiology—Approaches Developed in Aviation. Congen Cardiol Today 2008;6:1-10.
14. Daenen, W, Lacour-Gayet, F., Aberg, T., Comas, J., Daebritz, S., Di Donato, R., Hamilton, J., Lindberg, H., Maruszewski, B., Monro, J. Optimal structure of a congenital heart surgery department in Europe. Eur J Cardiothor Surg 2003;24:343-351.
15. Jacobs JP, Jacobs ML, Austin III EH, et al. Quality measures for congenital and pediatric cardiac surgery. World J Pediatr Congen Heart Surg 2012;3:32-47, doi:10.1177/2150135111426732.
16. Demographics of Europe. https://en.wikipedia.org/wiki/Demographics_of_Europe#/media/File:Europe_population_pyramid_from_1950_to_2023.gif. [accessed on 30 October 2024]
17. Europe birthrate trend 1950-2024. https://www.macrotrends.net/global-metrics/countries/eur/europe/birth-rate , www.macrotrends.net. [accessed on 30 October 2024]
18. Preston SH, Heuveline P, Guillot M. Demography: measuring and modeling population processes. Oxford, Blackwell, 2001:224.
19. Birthrate in China. https://www.macrotrends.net/global-metrics/countries/chn/china/birth-rate#:~:text=The%20current%20birth%20rate%20for,a%202.3%25%20decline%20from%202021. [accessed on 30 October 2024]
20. Birthrate in Japan. https://www.cia.gov/the-world-factbook/

field/birth-rate/#:~:text=Japan,1%2C000%20population%20(2024%20est. [accessed on 30 October 2024]

21. Bearak J, Popinchalk A, Ganatra B, Moller AB, Tunçalp Ö, Beavin C, Kwok L, Alkema L. Unintended pregnancy and abortion by income, region, and the legal status of abortion: estimates from a comprehensive model for 1990-2019. Lancet Global Health 2020; 8:e1152-e1161, https://doi.org/10.1016/S2214-109X(20)30315-6. https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(20)30315-6/fulltext
22. Dickinson DF, Arnold R, Wilkinson JL. Congenital heart disease among 160 480 liveborn children in Liverpool 1960 to 1969. Implications for surgical treatment. Br Heart J 1981;46:55-62. doi: 10.1136/hrt.46.1.55.
23. Lytzen R, Vejlstrup N, Bjerre J, et al. Live-Born Major Congenital Heart Disease in Denmark: Incidence, Detection Rate, and Termination of Pregnancy Rate From 1996 to 2013. JAMA Cardiol. 2018;3:829-837. https://doi:10.1001/jamacardio.2018.2009.
24. Congenital heart disease statistics 2006, British Heart Foundation, www.heartstats.org [accessed on 20 March 2008].
25. Bittles AH, Black ML, Govindaraju DR. Consanguinity, human evolution, and complex diseases. Proceedings of the National Academy of Sciences of the United States of America, 2010;107(Supplement 1: Evolution in Health and Medicine):1779-1786. http://www.jstor.org/stable/40536026.
26. Inbreeding by Country / Consanguinity by Country 2024. https://worldpopulationreview.com/country-rankings/inbreeding-by-country. [accessed on 12 December 2024]
27. Gev D, Roguin N, Freundlich E. Consanguinity and congenital heart disease in the rural Arab population in northern Israel. Hum Hered 1986;36:213-217. http://dx.doi.org/10.1159/000153628.
28. Becker SM, Al Halees Z, Molina C, Paterson RM. Consanguinity and congenital heart disease in Saudi Arabia. Am J Med Genet 2001;99:8-13. http://dx.doi.org/10.1002/1096-8628(20010215)99:1<8::aid-ajmg1116>3.0.co;2-u.
29. El Mouzan MI, Al Salloum AA, Al Herbish AS, Qurachi MM, Al Omar AA. Consanguinity and major genetic disorders in Saudi children: a community-based cross-sectional study. Ann Saudi Med 2008;28:169-73. doi: 10.5144/0256-4947.2008.169.
30. Townsend N, Bhatnagar P, Wickramasinghe K, Williams J, Vujcich D, Rayner M: Children and young people statistics 2013. British Heart Foundation, London, (2013). http://www.bhf.org.uk/plugins/PublicationsSearchResults/2013&resource=G694. [accessed on 7 July 2014]
31. European Union migration and migrant population statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Migration_and_migrant_population_statistics#:~:text=27.3%20million%20people%20(6.1%25),2023%20were%20non%2DEU%20citizens. [accessed on 15 December 2024.
32. Cody F, Franklin O, Mc Cay N. Critical congenital heart disease: contemporary prenatal screening performance and outcomes in a multi-centre perinatology service. BMC Pregnancy Childbirth 2024;24:163. https://doi.org/10.1186/s12884-024-06350-0.
33. Ngeow J-HA, Tan MG, Choo T-LJ, Tan TH, Tan WC, Chan DKL. Screening for congenital heart disease in a Singapore Neonatal Unit. Singapore Med J 2021;62:341-346. https://doi.org/10.11622/smedj.2019167.
34. Maruszewski B, Tobota Z. The European Congenital Heart Defects Surgery Database Experience: Pediatric European Cardiothoracic Surgical Registry of the European Association for Cardio-Thoracic Surgery. Ped Card Surg Annu Sem Thorac Cardiovasc Surg 2002;5:143-147.
35. Cattapan C, Jacobs JP, Bleiweis MS, Sarris GE, Tobota Z, Guariento A, Maruszewski B, Staffa SJ, Zurakowski D, Vida VL. Outcomes of Neonatal Cardiac Surgery: A European Congenital Heart Surgeons Association Study. Ann Thorac Surg 2024:S0003-4975(24)00637-4. doi: 10.1016/j.athoracsur.2024.07.023. https://www.annalsthoracicsurgery.org/article/S0003-4975(24)00637-4/abstract. [accessed on 19 October 2024.
36. Herbst C, Zhang H, Hu R, Hörer J, Ono M, Vida V, Ebels T, Kansy A, Jacobs JP, Tobota Z, Maruszewski B. Pediatric Cardiac Surgical Patterns of Practice and Outcomes in Europe and China: An Analysis of the European Congenital Heart Surgeons Association Congenital Heart Surgery Database. CHD. 2021;16:17-25. doi: 10.32604/CHD.2021.012982.
37. Vida VL, Zanotto L, Torlai Triglia L, Zanotto L, Maruszewski B, Tobota Z, Bertelli F, Cattapan C, Ebels T, Bottigliengo D, et al. Surgery for Adult Patients with Congenital Heart Disease: Results from the European Database. J Clin Med 2020;9:2493. https://doi.org/10.3390/jcm9082493.
38. European Congenital Heart Surgeons Association Database. Congenital heart surgery centers in Europe. https://echsacongenitaldb.org/cs_centers_european/. [accessed on 28 October 2024]
39. Population demographic data in Europe 2024. https://www.worldometers.info/population/countries-in-europe-by-population/. [accessed on 28 October 2024]
40. Population demographic data in Europe 2024. https://www.cia.gov/the-world-factbook/field/birth-rate/country-comparison/. [accessed on 28 October 2024]
41. European Commission on EU Healthcare policy. https://health.ec.europa.eu/eu-health-policy/overview_en. [accessed on 11 December 2024]
42. Merrill WH. What's past is prologue 1. Ann Thor Surg 1999;68:2366 -75.
43. Castañeda AR. The making of a cardiothoracic surgeon: an Apollonian quest. J Thorac Cardiovasc Surg 1994;108:806-812.
44. Lundström NR, Berggren H, Björkhem G, Jögi P, Sunnegårdh J. Centralization of pediatric heart surgery in Sweden. Pediatr Cardiol 2000;21:353-7. doi: 10.1007/s002460010079.
45. Durkin N, Davenport M. Centralization of Pediatric Surgical Procedures in the United Kingdom. Eur J Ped Surg 2017;27. Doi: 10.1055/s-0037-1607058.
46. Mayor S. Fewer, larger centres are needed to improve children's heart surgery, report says. BMJ 2010;340:c2341. doi: https://doi.org/10.1136/bmj.c2341. [accessed on 1 November 2024]
47. Vervoort D. Centralization and regionalization of congenital heart surgery in a globalized world. J Thor Cardiovasc Surge 2020;161:e481. https://doi.org/10.1016/j.jtcvs.2020.09.014
48. Ghandour HZ, Welke K, Karamlou T. The road to regionalization in congenital heart surgery: a narrative review. AME Surg J 2022;2:27. https://dx.doi.org/10.21037/asj-21-70.
49. Polk HC. The declining interest in surgical careers, the primary care mirage, and concerns about contemporary undergraduate surgical education. Am J Surg 1999;178:177-79.
50. Nagraj S, Wall D, Jones E. Trainees' perceptions of the current operating theatre educational environment. Ann R Coll Surg Engl 2007;89:358-360. DOI: 10.1308/147363507X245193
51. Mussa S, Drury NE, Stickley J. Mentoring new surgeons: can we avoid the learning curve? Eur J Cardiothorac Surg 2017;51:291-9.
52. Jacobs JP, Jacobs ML, Maruszewski B, et al. Initial application in the EACTS and STS Congenital Heart Surgery Databases

of an empirically derived methodology of complexity adjustment to evaluate surgical case mix and results. Eur J Cardiothorac Surg 2012;42:775-9; discussion 779-80.

53. Durko AP, Yacoub MH, Kluin J. Tissue Engineered Materials in Cardiovascular Surgery: The Surgeon's Perspective. Front Cardiovasc Med 2020;7:55. doi: 10.3389/fcvm.2020.00055
54. Ceneri NM, Desai MH, Tongut A, et al. Hybrid strategy in neonates with ductal-dependent systemic circulation and multiple risk factors. J Thorac Cardiovasc Surg 2022;164:1291-1303.e6.
55. Villa E, Vanden Eynden F, Le Bret E, et al. Paediatric video-assisted thoracoscopic clipping of patent ductus arteriosus: experience in more than 700 cases. Eur J Cardiothorac Surg 2004;25:387-93.
56. Gao C, Yang M, Wang G, et al. Totally endoscopic robotic atrial septal defect repair on the beating heart. Heart Surg Forum 2010;13:E155-8.
57. del Nido PJ. Minimal incision congenital cardiac surgery. Semin Thorac Cardiovasc Surg 2007;19:319-24.
58. Pugh S. Sometimes (excerpt) https://janicefalls.wordpress.com/2020/11/11/sometimes-by-sheenagh-pugh/ [accessed on 25 December 2024]