Uncovering the treatable burden of severe aortic stenosis in the UK

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ABSTRACT

Objective To estimate the population prevalence and treatable burden of severe aortic stenosis (AS) in the UK.

Methods We adapted a contemporary model of the population profile of symptomatic and asymptomatic severe AS in Europe and North America to estimate the number of people aged ≥55 years in the UK who might benefit from surgical aortic valve replacement (SAVR) or transcatheter aortic valve implantation (TAVI).

Results With a point prevalence of 1.48%, we estimate that 291 448 men and women aged ≥55 years in the UK had severe AS in 2019. Of these, 68.3% (199 059, 95% CI 177 201 to 221 355 people) would have been symptomatic and, therefore, more readily treated according to their surgical risk profile; the remaining 31.7% of cases (92 389, 95% CI 70 093 to 144 247) being asymptomatic. Based on historical patterns of intervention, 58.4% (116 251, 95% CI 106 895 to 125 606) of the 199 059 symptomatic cases would qualify for SAVR, with 7208 (95% CI 7091 to 7234) being assessed as being in a high, preoperative surgical risk category. Among the remaining 41.6% (82 069, 95% CI 73 453 to 92 164) of cases potentially unsuitable for SAVR, an estimated 61.7% (51 093, 95% CI 34 780 to 67 655) might be suitable for TAVI. We estimate that 172 859 out of 291 448 prevalent cases of severe AS (59.3%) will subsequently die within 5 years without proactive management.

Conclusions These data suggest a high burden of severe AS in the UK requiring surgical or transcatheter intervention that challenges the ongoing capacity of the National Health Service to meet the needs of those affected.

INTRODUCTION

Aortic stenosis (AS) is one of the most common acquired forms of heart valve disease requiring clinical intervention.1,2 As highlighted by the OxVALVE Study,3 a significant portion of the UK population (1.3% of their cohort of individuals age ≥65 years had undiagnosed AS) will remain undetected during their lifetime or experience a ‘late’ diagnosis when their condition reaches an advanced, symptomatic stage.4 The prevalence of AS correlates strongly with advancing age and is a major cause of death among older individuals.1,2 For example, within the large National Echocardiography Database of Australia (NEDA) patient cohort, the incidence of AS rose eightfold from 5 to 40 cases/1000 person-years among those aged <30 years to >80 years (overall incidence of ~18 cases/1000 person-years).5 Within this same cohort, the proportion of individuals who died with severe AS rose from 3.9% in those aged >65 years to 6.1% in those aged >85 years.6 Unfortunately, given the logistics of definitive screening with echocardiography, population studies such as the OxVALVE Study3 are scarce. Consequently, the natural history and subsequent disease burden of AS is often described from the perspective of those who are already diagnosed and receiving definitive treatment.

Of concern, in the context of a probable ‘iceberg’ of largely undetected and untreated cases of AS within progressively ageing high-income countries like the UK,7 is the high mortality associated with untreated severe AS, especially once symptoms develop.8 The mortality in such patients is reported to be as high as 50% at 2 years and 97% at 5 years.9 Poor survival rates associated with the full
spectrum of AS within the large, unselected NEDA cohort reaffirmed the potential to proactively identify and treat more individuals with severe AS. In common with the evolving trial evidence around aortic valve replacement (AVR), within the same cohort, the survival benefits conferred by successful AVR were striking. Such data highlight the potential for substantial public health benefits of earlier detection of AS, using the stethoscope and echocardiography, and subsequent rapid access to heart valve centres/clinics. This latent potential to increase the detection of AS was further highlighted in the NHS England’s Long-Term Plan 2019. However, until more definitive population studies of AS are conducted, it is difficult to accurately assess the size of the treatable population with severe AS and thereby plan clinical services to ensure potentially life-saving treatments are applied.

**STUDY AIMS**

The primary aim of this study was to determine how many people might be expected to need evidence-based treatment for severe AS in the UK in the near term based on expert guidelines for its optimal diagnosis and management. Specifically, we first sought to apply age-specific estimates of the prevalence of severe AS within the known UK population aged 55 years or older to calculate the likely number of individuals affected by severe AS overall (prevalent cases). We further sought to estimate how many individuals could be immediately identifiable/detected based on the presence of concurrent symptoms (diagnosed/treated cases). Finally, based on the historical application of surgical aortic valve replacement (SAVR) versus transcatheter aortic valve implantation (TAVI) for severe AS according to surgical risk (based on composite data derived from the UK, Europe and North America), we further aimed to quantify the likely demand for surgical services if all cases of severe AS were detected (surgical caseload).

**METHODS**

A pragmatic approach to estimate the treatable burden of disease imposed by severe AS in the UK was applied using similar methods previously used to derive what proved to be an accurate forecast of the contemporary and projected burden of heart failure in the UK. The same broad methods were also applied to an equivalent study of the treatable burden of AS in Australia. The primary basis for this study (in respect to providing AS-specific data) was two meta-analyses of AS that systematically reviewed and analysed the relevant public health to clinical literature to build contemporary models of the likely burden and treatment of severe AS. The most recent of these reports synthesised data from 9723 cases of severe AS from 7 studies (predominantly from North America and Europe/UK). A decision-making flowchart of severe AS (from the prevalent population to how they are then sequentially treated according to their probable symptomatic profile and surgical risk status) was then constructed. The sequential distribution of cases through the flowchart was informed by meta-analyses with beta distributions used at each step (using 10,000 Monte Carlo simulations) to derive the most accurate point estimates (with 95% confidence intervals, CIs) for each sequence. Critically, local reimbursement policies were not considered in determining who might or might not be treated with surgical intervention. Notwithstanding the rapidly evolving literature around the choice between SAVR versus TAVI and, indeed, the pattern of surgical risk that will undoubtedly influence future treatment pathways, this model provided a robust framework for estimating the treatable burden of severe AS in the UK.

**Summary model**

Figure 1 summarises the key steps applied to generate the estimates provided in this report with consideration of the UK population structure, the underlying prevalence of severe AS, their symptomatic status and their potential treatment based on their likely surgical risk profile—noting that each identified prevalent case is accounted for in the flowchart. Each of these steps (and their source data) are described below.

**UK population data**

To determine how many people within the UK are at risk of developing severe AS (our denominator/at risk population group), we first obtained age-specific and sex-specific population data for the calendar year 2019 from the UK Office of National Statistics (online supplementary figure 1). In that year, of the approximate 66 million people living in the UK, 30% were aged ≥55 years (20.1 million people). We also collated these data separately for England, Wales, Scotland and Northern Ireland to generate specific estimates for each geopolitical region.

**Age-specific prevalence of severe AS**

As our next step, we applied a point prevalence of 3.5% for severe AS among individuals in the UK aged ≥75 years. This represents a small increase in the age-specific prevalence rate compared to the original flowchart published by Durko and colleagues to reflect contemporary reports of an increasing incidence of AS in the UK. Unlike the original reports, we also focused on the likely burden of severe AS among those aged 55–74 years. To derive valid and accurate prevalence estimates for these age groups, we analysed the pattern of severe AS within the large and unselected NEDA cohort (one of the largest ever studies of all forms of AS to date). Using this cohort, we first validated an overall prevalence estimate of 3.5% severe AS among those aged 75 years and above as a conservative starting point for our analyses. We also noted the absence of any major sex-specific differences in this regard (concurring with the UK-based data from the OxVALVE Study). Using this age group (≥75 years) as a fixed reference point, we then used the observed age profile of severe AS cases below the age of 75 years within
Valvular heart disease

the NEDA cohort to derive the following age-specific prevalence estimates of severe AS to be applied to the UK population in the following age bands: aged ≥75 years (3.5%—index prevalence estimate), 70–74 years (1.2%), 65–69 years (0.7%), 60–64 years (0.5%) and 55–59 years (0.4%). This age-specific approach differs from the original reports where population estimates (European and North America) were also used as a starting point, but a single, rather than age-stratified, point-prevalence estimate for severe AS was applied. Critically, when these age-stratified estimates were applied to the UK population aged ≥55 years, they generated an overall point prevalence of severe AS that was congruent to that of the estimated prevalence of undetected AS cases within the OxVALVE Study cohort.3

Treatable cases

Having estimated the total number of individuals aged ≥55 years living in the UK with severe AS, we applied the same proportions and 95% CI developed (derived from meta-analyses of the published literature) and then applied by Durko and colleagues16 to determine what proportion of prevalent cases would be symptomatic versus non-symptomatic (this latter group being less likely to be detected and treated) (see figure 1). Of those considered to be symptomatic, we further stratified such individuals (once again using the original proportions and 95% CIs for these estimates16) according to their likely suitability for more conservative medical versus surgical treatment and the subsequent option of SAVR versus TAVI (see also figure 1). Specifically, as per the original flowchart/modelling, we distributed SAVR and TAVI treatment according to the likely perioperative risk profile of potentially treated cases according to the Society of Thoracic Surgeon’s Predicted Risk of Mortality Score (STS-PROM).20 In the absence of more specific UK data21 it is explicitly acknowledged that the distribution of cases according to their surgical risk and options for SAVR versus TAVI will potentially underestimate or overestimate the risk profile of cases and the number of procedures that might be applied both now and the immediate future.

5-year mortality

To provide an indicative estimation of the potential number of deaths linked to severe AS without proactive treatment in the UK based on the estimated total number of cases living with the condition in 2019, we applied actual 5-year mortality rates observed within the same age groups of the NEDA cohort who did not undergo AVR.6 Specifically, we assumed during the period 2019–2024, 17.0%, 37.5%, 43.7%, 49.1%, 58.6%, 69.2% and 83.7% of those individuals aged 55–59, 60–64, 65–69, 70–74,
75–79, 80–84 and ≥85 years, respectively, with severe AS (regardless of symptomatic status) would die of any cause.

Statistical analyses
All data are presented in descriptive form with 95% CI provided for the main estimates.

Patient and public involvement
Given the retrospective nature of study analyses, no participants were asked to advise on interpretation or writing of the manuscript.

RESULTS
Prevalence of severe AS (2019)
The overall estimated point prevalence of severe AS within the UK population aged 55 years and above in 2019 is 1.48%. As shown in figure 2 (top panel), this currently equates to around 300,000 UK men and women living with this potentially deadly condition at any one time. Of these, we estimate that just less than 200,000 people will present with symptomatic, severe AS (figure 2, bottom panel). The remainder of cases who remain asymptomatic (92,589 (95% CI ~70,000 to ~144,000) people) are unlikely to be detected/diagnosed unless subject to proactive screening for AS or undergoing investigation for another cardiac condition.

Treatment of severe symptomatic AS (2019)
Overall, we estimate that 82,809 out of 199,059 symptomatic individuals (95% CI ~74,000 to ~92,000) initially considered unsuitable for surgery would be treated with medical management. Of these cases, 51,093 individuals (95% CI ~35,000 to ~68,000) might be eligible for/benefit from TAVI. Among the remainder of symptomatic cases, we estimate that 116,251 (95% CI ~107,000 to ~126,000) individuals could be immediately considered for surgical intervention. As shown in figure 3 (distribution of SAVR procedures) figure 4 (distribution of TAVI procedures), based on the projected surgical risk profile of these 199,059 prevalent cases with symptomatic severe AS and the historical distribution of procedures used to treat them, around 116,000 and 51,000 SAVR and TAVI procedures respectively, would be therapeutically indicated.

5-year mortality among all prevalent cases
Depending on the type of treatment applied, it is estimated that up to 172,859 of the 291,448 prevalent cases...
Valvular heart disease

Valvular heart disease is a common condition affecting the heart valves. It is characterized by the narrowing or blocking of the blood flow through the heart valves, which can lead to various symptoms and complications. The most common form of valvular heart disease is aortic stenosis (AS), which is a narrowing of the aortic valve. AS can be caused by age-related calcification of the valve, or it can be congenital. The condition can lead to heart failure, atrial fibrillation, and other complications if left untreated.

The prevalence of severe AS in the UK is estimated to be around 70,000 people aged 60 years and over, with an annual rate of 3,500 new cases. The condition is more common in older adults, with a peak incidence in the seventh decade of life. The natural history of AS is unpredictable, and the prognosis of severe AS is poor, with an annual mortality rate of about 5%.

There are several treatment options for AS, including medical therapy, invasive procedures, and surgical interventions. Medical therapy is usually the first line of treatment and includes medications to reduce the workload on the heart and improve symptoms. Invasive procedures, such as balloon valvuloplasty or percutaneous valve replacement, can be used in younger patients with mild to moderate AS.

Surgical interventions, such as aortic valve replacement (AVR), are considered for patients with severe AS or those who are at high risk of adverse outcomes. AVR can be performed through an open surgical approach or using minimally invasive techniques, such as transcatheter aortic valve implantation (TAVI). The choice of treatment depends on the patient's age, comorbidities, and surgical risk profile.

The prognosis of severe AS is poor, with a mortality rate of about 5% per year. However, early detection and prompt treatment can improve outcomes. Therefore, it is important to screen and diagnose AS early to prevent complications and improve patient outcomes.

Overall, valvular heart disease is a significant public health problem, requiring a multidisciplinary approach to diagnosis, treatment, and management. Further research is needed to improve our understanding of the natural history of the condition and to develop new treatments to improve outcomes.
AS, especially once associated with symptoms, is often worse than most cancers.\(^1\) The potential value of early detection of AS and guideline driven interventional treatment in severe AS is substantial, given the evidence that such procedures prolong life.\(^{2,11}\) However, realising this life-saving potential requires an understanding of

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**Figure 4** Estimated cases of severe, symptomatic aortic stenosis (AS) in the UK considered for transcatheter aortic valve implantation (TAVI) (2019). This figure shows the estimated number (with 95% CI) of prevalent cases aged ≥55 years who would be considered too high risk for surgical aortic valve replacement (SAVR) but instead be potential candidates for TAVI (sequential estimate rates for both provided in the red boxes).

**Figure 5** Summary of the estimated (prevalent) burden and management of severe aortic stenosis (AS) in the UK (2019). SAVR, surgical aortic valve replacement; TAVI, transcatheter aortic valve implantation.
the true size of the population with severe AS who would benefit from treatment and the resources required to meet their therapeutic needs. Building on a previously published model\textsuperscript{15} with specific adjustments derived from NEDA\textsuperscript{3}, we applied a robust set of estimates to determine the treatable burden of severe AS within the UK population. Beyond establishing the existence of a large prevalent population of severe AS (around 300,000 people), we further estimate that around 28,000 will newly develop this condition each year. To place these figures into a clinical capacity/health service context, in the year 2018–2019 the following procedures were reported to the national audits: 5197 TAVI, 5091 isolated SAVR and 2739 combined SAVR combined with coronary artery bypass grafting (a total of 13,027 procedures).\textsuperscript{25} The surgical figures include those from Ireland, and some surgical procedures will have been undertaken for aortic regurgitation rather than AS but making some allowance for this it would be reasonable to suggest that around 10,000 procedures were undertaken in the UK that year for severe AS, representing around 50% of the total we have projected to be developing symptomatic severe AS each year, and therefore being potential candidates for surgical or transcatheter intervention. There seems little doubt therefore that there is a significant shortfall between interventions undertaken for severe AS and our estimates of potential demand. Critically, our estimates of the treatable burden of AS are consistent with the limited data reported previously\textsuperscript{5,6} and our overall prevalence estimate of 1.48% is congruent with the 1.3% prevalence of undetected AS in the OxVALVE Study.\textsuperscript{3} However, even a small difference between the estimated prevalence (1.48% when combining all-age-specific rates applied) versus actual prevalence of severe AS in the UK will increase the magnitude of error across our projections. Given the substantial cost of treating AS, such uncertainty reinforces the need for contemporary studies of the population and clinical epidemiology of this potentially deadly and disabling condition.\textsuperscript{7}

The NHS Long Term Plan (2019) highlighted the need for better detection of heart valve disease and access to specialist care for these patients.\textsuperscript{12} The current study provides estimates for the burden of severe AS, and the likely number of SAVR and TAVI procedures that will be needed to treat this population in an optimal time frame, so that commissioners, and other professionals delivering care, can plan services appropriately. Specifically, the estimated demand will assist the planning of screening processes in primary care (noting the more than 90,000 cases estimated to be asymptomatic), and quicker access to secondary care assessment, and receive AVR where appropriate. The requirements for expansion of current facilities, improved training of staff and increased staff numbers will be much easier to estimate based on the modelling produced by this and other research. It will also allow for service improvements that are consistent with national standards and guidelines, such as those soon to be published by the National Institute for Health & Care Excellence (NICE) and the Getting it Right First Time programme. Recent data from the UK reveals concerning trends with regard to the inequitable access to TAVI, under provision of TAVI for severe symptomatic AS patients, and high rates of mortality for patients on TAVI waiting lists.\textsuperscript{13} Further, recent data from the UK NICOR dataset highlight the detrimental effect of the COVID-19 pandemic on provision of both SAVR and TAVI for existing patients with AS.\textsuperscript{21} Such data highlight the need for a robust and equitable plan to deliver potentially life-saving services to a growing number of people in the UK already affected, or soon to be, by severe AS.

**LIMITATIONS**

It is important to note that beyond largely reliable population statistics (the dynamics of which are most important in driving burden of disease estimates), we currently have no means to verify if our overlaying estimates of the prevalence/incidence and treatable burden of disease are correct. Where possible, we have sought to corroborate these vital statistics via the large NEDA cohort.\textsuperscript{5,6} We also applied the 95% CI around the key estimates that were synthesised by Durko and colleagues via meta-analyses and Monte Carlo simulations of data from a broad range of countries. However, as noted in the current ESC/EACTS guidelines, STS-PROM Scores are inherently variable, and these will influence treatment options.\textsuperscript{22}

Notably, beyond a population-based report from the Tromsø Study,\textsuperscript{26} the underlying prevalence and incidence of AS at the whole population level remains poorly characterised. Thus, all our estimates should be cautiously interpreted.

**SUMMARY**

In conclusion, this study suggests that severe AS is a common condition affecting many individuals within the UK population aged \( \geq 55 \) years. Without appropriate detection and intervention, their survival prospects are likely to be poor. However, the indicative treatable burden of disease (around 20,000 new, potentially treatable cases each year) is discordant with current capacity within the NHS to deliver AVRs in the form of SAVR or TAVI (regardless of the ratio in which these two different procedures might be applied).

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Strange GA, et al. *Open Heart* 2022;9:e001783. doi:10.1136/openhrt-2021-001783
REFERENCES

1. Nkomo VT, Gardin JM, Skelton TN, et al. Burden of valvular heart diseases: a population-based study. JAMA 2006;296:1005–11.

2. Beyersdorf F, Pras F, Milojic M. 2021 ESC/EACTS guidelines for the management of valvular heart disease. Eur Heart J 2021;00:1–72.

3. d’Arcy JL, Coffey S, Loudon MA, et al. Large-scale community echocardiographic screening reveals a major burden of undiagnosed valvular heart disease in older people: the OxVALVE population cohort study. Eur Heart J 2016;37:3515–22.

4. Nchimi A, Dibato JE, Davin L, et al. Predicting disease progression and mortality in aortic stenosis: a systematic review of imaging biomarkers and meta-analysis. Front. Cardiovasc. Med. 2018;5:112.

5. Stewart S, Chan Y-K, Playford D, et al. Incident aortic stenosis in 49 449 men and 42 229 women investigated with routine echocardiography. Heart 2021;107:319697.

6. Strange G, Stewart S, Celermajer D, et al. Poor long-term survival in patients with moderate aortic stenosis. J Am Coll Cardiol 2019;74:1851–63.

7. Strange G, Scalia GM, Playford D, et al. Uncovering the treatable burden of severe aortic stenosis in Australia: current and future projections within an ageing population. BMC Health Serv Res 2021;7:190.

8. Frey N, Steeds RP, Rudolph TK, et al. Symptoms, disease severity and treatment of adults with a new diagnosis of severe aortic stenosis. Heart 2020;106:1792–7.

9. Lancellotti P, Magne J, Dulgheru R, et al. Outcomes of patients with asymptomatic aortic stenosis followed up in heart valve clinics. JAMA Cardiol 2018;3:1060–8.

10. San Román JA, Vilacosta I, Antunes MJ, et al. The ‘wait for symptoms’ strategy in asymptomatic severe aortic stenosis. Heart 2020;106:1792–7.

11. Playford D, Stewart S, Celermajer D, et al. Poor survival with impaired valvular hemodynamics after aortic valve replacement: the National echo database Australia study. J Am Soc Echocardiogr 2020;33:1077–86.

12. National Health Service. 2021. Available: https://www.longtermplan.nhs.uk [Accessed May 2021].

13. Ali N, Faour A, Rawlins J, et al. ‘Vale for life’: tackling the deficit in transcatheter treatment of heart valve disease in the UK. Open Heart 2021;8.

14. Chambers JB. Aortic stenosis: service delivery before guidelines. Heart 2019;105:1686–7.

15. Osnabrugg RLJ, Mylotte D, Head SJ, et al. Aortic stenosis in the elderly: disease prevalence and number of candidates for transcatheter aortic valve replacement: a meta-analysis and modeling study. J Am Coll Cardiol 2013;62:1002–12.

16. Durko AP, Osnabrugg RL, Van Mieghem NM, et al. Annual number of candidates for transcatheter aortic valve implantation per country: current estimates and future projections. Eur Heart J 2017;38:2635–42.

17. Stewart S, MacIntyre K, Capewell S. Heart failure and the aging population: an increasing burden in the 21st century? Heart 2003;89:49–53.

18. Population estimates for the UK, England and Wales, Scotland and Northern Ireland - Office for National Statistics (ons.gov.uk).

19. Nazarzadeh M, Pinho-Gomes A-C, Bidel Z, et al. Plasma lipids and risk of aortic valve stenosis: a Mendelian randomization study. Eur Heart J 2020;41:3913–20.

20. Serruys PW, Modolo R, Reardon M, et al. One-Year outcomes of patients with severe aortic stenosis and an STS PROM of less than three percent in the SURTAVI trial. EuroIntervention 2018;14:877–83.

21. Martin GP, Curzen N, Goodwin AT, et al. Indirect impact of the COVID-19 pandemic on activity and outcomes of transcatheter and surgical treatment of aortic stenosis in England. Circulation 2021;14:e010413.

22. Otto CM, Baumgartner H. Updated 2017 European and American guidelines for prosthesis type and implantation mode in severe aortic stenosis. Heart 2018;104:710–3.

23. Rosenhek Ret al. Mild and moderate aortic stenosis natural history and risk stratification by echocardiography. Eur Heart J 2004;25:199–205.

24. Delesalle G, Bobbot Y, Ruisinaru D, et al. Characteristics and prognosis of patients with moderate aortic stenosis and preserved left ventricular ejection fraction. J Am Heart Assoc 2018;8:e01036.

25. Adult Cardiac Surgery (Surgery Audit). National Institute for cardiovascular outcomes research (NICOR). Available: https://www.nicor.org.uk/national-cardiac-audit-programme/adult-cardiac-surgery-surgery-audit/ [Accessed Jun 2021].

26. Eveborn GW, Schirmer H, Heggelund G, et al. Incidence of aortic stenosis in subjects with normal and slightly elevated aortic gradients and flow. Heart 2015;101:1895–900.