The role of phacoemulsification surgery in the incidence rate of rhegmatogenous retinal detachment

Nielsen, Birgitte Romme; Alberti, Mark; Høgild, Morten Lyng; Bek, Toke; Thinggaard, Benjamin Sommer; Grauslund, Jakob; Christensen, Ulrik; la Cour, Morten

Published in:
Acta Ophthalmologica

DOI:
10.1111/aos.16723

Publication date:
2024

Document version:
Final published version

Received: 5 January 2024 | Accepted: 11 May 2024

DOI: 10.1111/aos.16723

Acta Ophthalmologica

ORIGINAL ARTICLE

The role of phacoemulsification surgery in the incidence rate of rhegmatogenous retinal detachment

Birgitte Romme Nielsen[1,2] | **Mark Alberti**[1] | **Morten Lyng Høgild**[3] | **Toke Bek**[3] | **Benjamin Sommer Thinggaard**[4,5,6] | **Jakob Grauslund**[5,6] | **Ulrik Christensen**[1,2] | **Morten la Cour**[1,2]

[1]Department of Ophthalmology, Rigshospitalet – Glostrup, Copenhagen, Denmark

[2]Faculty of Health Sciences, University of Copenhagen, Copenhagen, Denmark

[3]Department of Ophthalmology, Aarhus University Hospital, Aarhus, Denmark

[4]OPEN Data Explorative Data Network, Odense University Hospital, Odense, Denmark

[5]Department of Clinical Research, University of Southern Denmark, Odense, Denmark

[6]Department of Ophthalmology, Odense University Hospital, Odense, Denmark

Correspondence
Birgitte Romme Nielsen, Department of Ophthalmology, Rigshospitalet – Glostrup, Copenhagen, Denmark.
Email: birgitte.romme.nielsen@regionh.dk

Funding information
Candys Foundation; Synoptik-Fonden; RH-OUH Research Foundation; Fight for Sight, Denmark; Helsefonden

Abstract

Purpose: To investigate changes in the incidence rate of primary rhegmatogenous retinal detachment (RRD) surgery over time and to determine to what extent these changes can be attributed to pseudophakia.

Methods: This nationwide cohort study was based on national patient registries. The study population comprised individuals at risk of RRD aged 40 years and above from 2006 to 2021 in Denmark. The primary outcome was RRD incidence, and the exposure was phacoemulsification surgery. A chart review was conducted to validate and examine the lens status of the outcome.

Results: The crude and age-adjusted incidence rate of RRD in the Danish population increased significantly during the study period. The largest increase in RRD was seen in phakic RRD (phRRD) (65%), whereas pseudophakic RRD (pRRD) accounted for 35% of the total increase. A chart review revealed that 17% of phRRDs were misclassified as pseudophakic, resulting in pRRD accounting for a total of 45% of the increase in RRD. The prevalence of pseudophakia in Denmark grew significantly for all age groups and for both sexes ($p = 10^{-6}$) from 2006 to 2021, but the 1-year incidence of pRRD in the pseudophakic population was constant throughout the entire period.

Conclusion: The incidence rate of RRD is continuing to increase in Denmark. The increase in phRRD remains undetermined, and while the risk of pRRD seemed to be constant during the study period, 45% of the overall increase in RRD could be attributed to the rise of a growing pseudophakic population.

KEYWORDS
incidence rate, phacoemulsification surgery, register-based study, rhegmatogenous retinal detachment

1 | INTRODUCTION

In recent years, multiple studies have identified a notable rise in the age- and sex-adjusted incidence rate of RRD among individuals aged 50 years and above (Achour et al., 2022; El-Abiary et al., 2022; Nielsen et al., 2020; van Leeuwen et al., 2020). This is indeed concerning because, even with timely surgical intervention, RRD can cause irreversible vision loss (Pastor Jimeno et al., 2008).

The known risk factors for RRD are age, sex, myopia, trauma and intraocular surgery (Bjerrum et al., 2013; Chen et al., 2016; Mitry et al., 2010), but only a few studies have explored the underlying reasons for the increased incidence rate of RRD (Achour et al., 2022; van Leeuwen et al., 2020). The prevalence of myopia has been rising for decades in the Asian population, and recent studies indicate that the prevalence is also increasing in Europe (Holden et al., 2016; van Leeuwen et al., 2020). Nevertheless, a systematic review from 2021 found no evidence that the prevalence of myopia has been increasing during the last century in Denmark (Hansen et al., 2021).

The incidence of phacoemulsification surgery has been steadily increasing since its introduction in 1990 (Solborg Bjerrum et al., 2015). This is probably due to

the ageing of the population and the ensuing increased incidence of visual impairment due to the development of age-related cataracts (Høeg et al., 2016; Lundström et al., 2001). However, the lower thresholds for surgery (Lundström et al., 2015; Solborg Bjerrum et al., 2015) and the expanding market for refractive lens extraction (Alio et al., 2014) might also be contributing to the observed increase.

Our objective was to investigate whether the incidence rate of primary RRD continued to increase from the time we ended our last study in 2016 (Nielsen et al., 2020). We also aimed to determine the extent to which the growing incidence rate could be attributed to the use of phacoemulsification surgery.

2 | MATERIALS AND METHODS

2.1 | Study population

The study population comprised individuals with a permanent residency in Denmark aged 40 years and above who were at risk of a primary RRD from 1 January 2006 to 31 December 2021. A primary RRD was defined as the first recorded RRD repair surgery in an individual with no prior recorded history of intraocular surgery apart from phacoemulsification. To ensure the inclusion of only those individuals who were at risk of primary RRD, we identified individuals with any recorded excluding event prior to their entry date. We were able to identify exposure or exclude events by accessing data reaching 10 years prior to the entry date (1 January 1996). Excluding events encompassed all intraocular surgeries, including phacoemulsification surgery performed in combination with other intraocular surgeries, except for anterior vitrectomy (Table S1). Thus, phacoemulsification surgery as a mono procedure performed in an individual at age 40 or above for either age-related cataract or ametropia was deemed an exposure and not an excluding event. The total cumulated person-years for individuals with an excluding event were subtracted from the total person-years of the included individuals. We excluded individuals based on the first recorded surgery in either eye due to the occasional missing information on laterality. Inclusion of potential delayed registration of diagnoses and surgical procedures was possible, as data were accessed 6 months after the study ended. Individuals contributed risk time until outcome, emigration, death or censoring event (Table S1) in either eye.

2.2 | Data source

This nationwide retrospective cohort study was based on data from Statistics Denmark and four national Danish registries: the National Patient Registry (NPR), the Health Authority's registry of Danish patients treated at foreign hospitals and activity in specialist medical practices (DUSAS), the National Health Insurance Service Register (NHI) and the Danish Civil Registration System (CPR registry) (Table S2). Healthcare in Denmark is government funded, and all ophthalmological procedures and diagnoses for the entire Danish population are recorded in these national registries. All registries can be combined because of the unique civil registration (CPR) number that is given to every Danish citizen at birth or to immigrants who permanently reside in Denmark (Schmidt et al., 2014, 2015).

2.3 | Exposure

In this study, exposure was defined as the first phacoemulsification surgery in an individual aged 40 years or above (Table S3). We included individuals with phacoemulsification surgery dating back to 1994. We followed all included individuals from the first exposure (e.g. phacoemulsification surgery) until the outcome, death, emigration or censoring event. Censoring events are listed in Table S1. We did not exclude individuals with combined phacoemulsification and anterior vitrectomy registration in the NPR because cataract surgery registered in the NHI lacks information regarding the anterior vitrectomy subprocedure. Excluding anterior vitrectomy could therefore have introduced bias, and our aim was to study the overall incidence of phacoemulsification surgery, irrespective of specific events that occurred during the procedure.

For each individual and year, we calculated the number of person-years contributed within the relevant age groups (40–49, 50–59, 60–69, 70–79 and 80+) to determine the prevalence of pseudophakic individuals at risk of a primary pRRD.

We followed individuals who had undergone phacoemulsification surgery for a maximum of one year to estimate the 1-year incidence rate of pRRD within the pseudophakic population. Individuals were followed from the first phacoemulsification surgery until outcome, emigration, death, censoring events in either eye or the end of the first postoperative year, whichever came first.

2.4 | Phakic individuals

The risk time (person-years) of phakic individuals at risk of a primary RRD was calculated by subtracting the number of person-years of pseudophakic individuals, as defined above, from the risk time of the entire study population.

2.5 | Outcome

The outcome was defined as the first primary RRD surgery in an individual aged 40 years or above (Table S3). A primary RRD was defined as pseudophakic in cases involving a preceding phacoemulsification surgery or in the presence of a diagnosis code of intraocular lens at the time of RRD surgery. We had at least 10 years

to retrospectively evaluate whether individuals had undergone phacoemulsification surgery prior to the first incident of RRD, since we had data from 1996 onwards and the study period started in 2006. A phakic primary RRD was defined as there being no recorded phacoemulsification surgery before the first RRD surgery or as cases involving a preceding phacoemulsification surgery that had been done on the opposite eye to that of the RRD surgery, as indicated by the laterality code.

2.6 | Data quality

We conducted a chart review in the five largest Danish university hospitals (Rigshospitalet – Glostrup, Zealand, Odense, Aarhus and Aalborg) for patients aged 40 years or above with a primary RRD surgery recorded during the study period (2006–2022). The first objective of this chart review was to assess our outcome validity, that is how many cases recorded as primary RRD in the registry met our criteria for a primary RRD. This validation was conducted by ophthalmologists, and we validated it in four out of the five hospitals.

Secondly, we aimed to examine the lens status of patients with primary RRD due to the occasional missing laterality of phacoemulsification surgery and/or RRD surgery and because the documentation of phacoemulsification surgery in the Danish registries is incomplete (Solborg Bjerrum et al., 2013). In the majority of cases, the lens status at the time of RRD surgery could be established with certainty from the data in the registries. Thus, we considered the lens status as pseudophakic with certainty if there was a laterality code for the RRD repair surgery and a preceding phacoemulsification surgery with the same laterality code. We also considered the lens status as pseudophakic with certainty if bilateral phacoemulsification surgery had been recorded prior to RRD repair surgery. Finally, if a diagnosis code for an intraocular lens implant (DZ961) had been added to the RRD repair surgery registration, the lens status was also considered pseudophakic with certainty. Patients were considered phakic with certainty if the RRD repair surgery was followed by a phacoemulsification in the same eye or in both eyes if lateralisation data were missing. For these cases, we did not perform chart reviews. When the registry data left us uncertain about the true pseudophakic and phakic status at the time of RRD, we conducted chart reviews for randomly selected cases. We aimed to achieve a chart review size that would result in a margin of error (confidence level) of less than 5% in the different subgroups. The lens status of pseudophakic cases was considered uncertain if laterality data were missing in cases where only one phacoemulsification surgery preceding RRD surgery had been reported. We considered phakic cases as uncertain if a preceding phacoemulsification surgery had a laterality code opposite that of the RRD surgery (phacoemulsification surgery is often performed on both eyes). We also considered the lens status uncertain if no phacoemulsification surgery had been registered before the primary RRD because unregistered phacoemulsification surgery could have been performed (Solborg Bjerrum et al., 2013).

2.7 | Permissions and ethics

Permission to conduct the study was obtained from the Danish Patient Safety Authority (permission no. P-2020-972). Approval to access medical charts was granted by the Danish Society for Patient Safety (Journal number R-20064223 and file number: 3-3013-1757/1). The study was conducted in accordance with the tenets of the Helsinki Declaration.

2.8 | Statistics

Data management and analysis were conducted using R, version 4.2.2.

To calculate the annual incidence rate of primary RRD, we used the crude numbers of RRD, both overall and stratified by sex and lens status, and divided them by the mid-year Danish population at risk of RRD for each year. The mid-year population was determined by calculating the average population at the start of each year.

To adjust for demographic changes in the Danish population at risk of RRD during the study period, we calculated the age- and sex-adjusted incidence rate of primary RRD by standardising the annual incidence rates for the Danish population at risk of primary RRD in the year 2006 (National Cancer Institute, 2006).

To study the rate of pRRD within the pseudophakic population over the study period, we restricted the follow-up time to 1 year after phacoemulsification surgery because the risk of pRRD within the pseudophakic population, may have varied from the time since the phacoemulsification surgery. We used Poisson regression, but now the offset in the model was person-years at risk of pseudophakia for each specific year. To calculate the incidence rate of phRRD in the phakic population we observed the number of phRRD cases in each of the five age groups relative to the total number of persons at risk of primary RRD in the Danish population. The same statistical approach as described above was used, but the offset was phakic person-years at risk of phRRD. For both statistical models, we adjusted for age by classifying age into five groups (40–49, 50–59, 60–69, 70–79 and 80+).

The annual change in incidence rates was quantified using the incidence rate ratio (IRR), derived from a Poisson regression model with a linear time effect on the log rates. We defined the annual change as the difference in incidence rates between consecutive years.

To determine the attribution of pseudophakia to the total increase in the crude incidence rate of RRD in females and males, we used predicted linear incidence rates to minimise random fluctuations. The predicted incidence rates were obtained from the Poisson model by a linear time effect on the log rate. We calculated the predicted linear incidence rate difference (IRD) for both the total RRD and pRRD for 2021 and 2006, separately for females and males. Finally, we calculated the ratio by

dividing the IRD for pRRD by the IRD for total RRD (Table 3).

Poisson regression was used to estimate the total change in prevalence of pseudophakia in 2021 versus 2006 in the study period (2006–2021), stratified by sex and age groups. The offset in the Poisson regression was persons at risk of primary RRD for every year for each age and sex strata.

A p-value <0.05 was considered statistically significant, and we applied Bonferroni correction for the p-value when multiple testing was performed.

3 | RESULTS

3.1 | Incidence rate of primary RRD in the Danish population

We found a total of 13 038 individuals with primary RRD, where 3542/13 038 (27%) had been registered as pseudophakic and 9496/13 038 (73%) as phakic at the time of RRD (Table 1). Primary RRD occurred later in individuals that were pseudophakic as compared to phakic individuals. Laterality data were available for 94% of cases with a primary RRD (i.e. which eye was operated on). We observed a significant and continuous rise in the crude incidence rate of primary RRD per 100 000 person-years at risk of primary RRD in the entire Danish population from 2006 until 2022 (Figure 1 – solid line). Overall, we found a 4.1% (95% CI 3.7–4.5, $p<10^{-16}$) annual increase in the incidence rate of RRD. Additionally, we observed that pRRD had a larger increase compared to phakic RRD (Table 2). When we stratified by sex and lens status, we found a significant annual increase in the incidence rate of RRD across all sexes and lens statuses (Table 2).

To ensure that the observed increase in incidence rate was not because of changes in age and sex distribution over time, we adjusted for age and sex by standardising the Danish population in 2006. We also found a significant increase in the age- and sex-adjusted incidence rate of RRD in males and females ($p<10^{-16}$, Figure 1 – dotted line).

To calculate the contribution of pseudophakia to the total increase in incidence of primary RRD, we used the predicted linear incidence rates stratified by sex (Table 3). For females and males, the attribution of pseudophakia to the total increase in primary RRD was 35.0% and 34.0%, respectively, prior to correcting for misclassification.

TABLE 1 Demographics of primary rhegmatogenous retinal detachment (RRD) in individuals.

	Pseudophakic RRD ($n=3542$)	Phakic RRD ($n=9496$)
Females, *n* (%)	1283 (36%)	3716 (39%)
Males, *n* (%)	2259 (64%)	5780 (61%)
Age, median (Q1-Q3)		
Females	71.6 (63.3–77.5)	61.5 (55.2–68.2)
Males	66.6 (59.7–73.5)	61.4 (54.9–67.8)
Time from first phacoemulsification surgery, median days (Q1–Q3)		
Females	1137.0 (403.5–2354.0)	
Males	880.5 (336.0–1822.8)	
Missing lateralisation		
Females, *n* (%)	338 (6.7%)	
Males, *n* (%)	499 (6.2%)	

Abbreviations: Q1, 1st quartile; Q3, 3rd quartile; RRD, rhegmatogenous retinal detachment.

3.2 | Incidence rate of pseudophakic RRD and phakic RRD

The 1-year incidence rate of pRRD in the pseudophakic population did not change significantly over time, even when we adjusted for age ($p=0.3$), (Figure 2).

The annual incidence rate of phRRD increased significantly over time, with an annual increase of 3.5% (95% CI: 2.8–4.3, p-value$=10^{-16}$) and 4.2% (95% CI: 3.7–4.9, p-value$=10^{-16}$) for females and males, respectively (Figure 2). This remained statistically significant after adjusting for age (both p-values$=10^{-16}$).

3.3 | Phacoemulsification surgery

We identified 559 917 individuals who had their first phacoemulsification surgery at the age of 40 or above: 340 300 females and 219 617 males. The mean age at first phacoemulsification surgery was 75.2 years (SD: 8.9) for females and 74.1 years (SD: 9.4) for males. Most of the phacoemulsification surgeries were registered in the NPR (74%), but a smaller proportion of them were registered in the NHI (23%) and DUSAS (3%) (Figure 3). Of the phacoemulsification surgeries, 29% were missing lateralisation. Of the total number of phacoemulsification surgeries since 1994, there were 1339 out of 559 917 (0.2%) who simultaneously underwent anterior vitrectomy. A total of 22 out of 1339 (1.6%) individuals had RRD following phacoemulsification surgery with a posterior capsular rupture. Thus, registered posterior capsular rupture was not a significant factor in explaining the increase in the number of pRRDs observed in the study period.

The prevalence of at least one pseudophakia within the population at risk of primary RRD is shown in Figure 4. We stratified the individuals by sex and age group and found a statistically significant increase in the prevalence of pseudophakia across all age groups and in both sexes ($p<10^{-7}$). The rate of this increase seems to be diminishing for the oldest age group (80+ years) over the most recent decade (Figure 4).

3.4 | Chart review

We chart-reviewed 982 patients operated for primary RRD between 2006 and 2022 in four of the Danish University Hospitals to assess the validity of our primary outcome. A total of 96% were correctly registered as primary RRD, and 44/982 (4%) patients were incorrectly

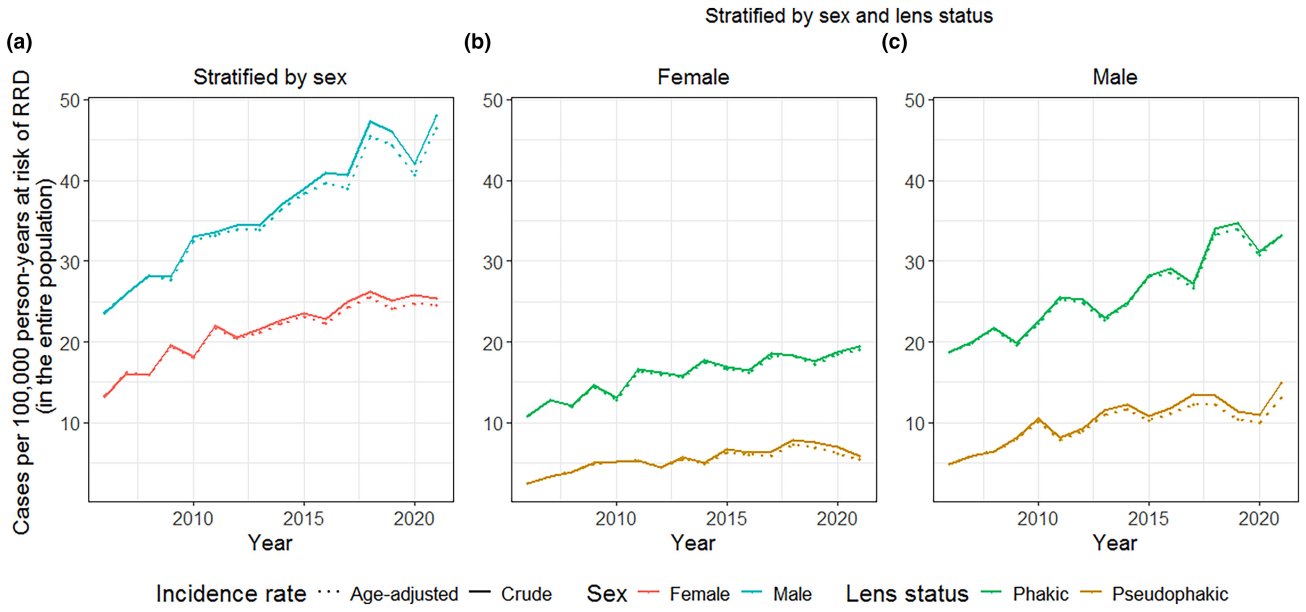

FIGURE 1 Crude and age-adjusted incidence rates of RRD in the entire Danish population at risk of primary RRD: (a) Overall incidence rate of primary RRD stratified by sex; (b) female incidence rate of primary RRD stratified by lens status at the time of primary RRD and (c) male incidence rate stratified by lens status at the time of primary RRD. Abbreviations: RRD, rhegmatogenous retinal detachment.

TABLE 2 Mean annual change of crude incidence rate of RRD given in incidence rate ratio overall and stratified by sex and lens status.

	Incidence rate ratio (95% CI)		
	Overall		***p*-Value**
All RRD	4.1 (3.7–4.5)		$p<10^{-16}$
Phakic	3.7 (3.2–4.1)		$p<10^{-16}$
Pseudophakic	5.3 (4.5–6.0)		$p<10^{-16}$
	Male	**Female**	
All RRD	4.3 (2.3–4.9)	3.7 (3.0–4.3)	$p<10^{-16}$*
Phakic	4.0 (3.4–4.6)	3.2 (2.4–3.9)	$p<10^{-16}$*
Pseudophakic	5.3 (4.4–6.3)	5.2 (3.4–6.3)	$p<10^{-15}$*

**p*-Value for both males and females.

coded in the NPR, with the most common reason being that they did not have retinal detachment ($n=14$), followed by aphakia at the time of primary RRD ($n=7$) and re-detachment ($n=9$) (Figure S1).

To assess the validity of the exposure, we chart reviewed 1396 RRD cases, where the registry left uncertainty concerning the lens status of the case (Table 4). For the 3542 RRD cases that were deemed pseudophakic per the registry, 203 cases were deemed with uncertain lens status, while the remaining 3339 were considered pseudophakic with certainty. We identified and reviewed charts from 172/203 (85%) of these uncertain cases and found 10/172 (6%) cases that were misclassified as they were in fact phakic. When extrapolating to the total population of pRRD, we found that 12/3542 (0.3%) of all pRRDs were misclassified.

Among the 9496 cases deemed phakic per the registry, we found that 65% of those were deemed with uncertain lens status (Table 4). In 6065 of these cases, there was no phacoemulsification surgery recorded before or after the RRD-operated eye, or phacoemulsification surgery was without lateralisation. For these cases, we randomly selected 1134/6065 cases (18.7%) where a chart review was performed, and 192/1134 cases (16.9%) were misclassified as they were in fact pseudophakic. In the study population, we found 98 nominally phRRD cases that were deemed uncertain because they had undergone a unilaterally-registered phacoemulsification operation prior to their first RRD, but where the laterality differed between the two operations. We performed chart review in 87/98 (88.8%) of these cases and found that 59/87 (67.8%) were misclassified, as they were in fact pseudophakic. We observed no trend of misclassification over the years among the pseudophakic or phakic individuals.

Extrapolating from our chart review results, we estimated that 4657/13038 (35.7%) individuals had a primary pRRD and 8381/13038 (64.3%) had a primary phRRD during the study period (as opposed to the 3542 pRRD cases and 9496 phRRD cases reported in the registries). Thus, the pseudophakic population was 1.32 times larger than had been recorded in the registry, and the phakic population was correspondingly 88% smaller (Table 4). This correction also applied to the distribution of the increase in RRD incidence in the entire population at risk of primary RRD. Unfortunately, our limited sample size hindered us from addressing age-specific misclassifications over time and thus prevented us from recalculating age- and sex-adjusted incidence rates. With the correction, 44.9% of the overall growth in primary RRD in females within the study period can thus be attributed to the increased pseudophakic female population. For males, with the correction, 45.7% of the overall growth in primary RRD in males can be attributed to the increased pseudophakic male population.

4 | DISCUSSION

We previously reported that the incidence rate of primary RRD in Denmark started to increase around 2005

TABLE 3 Predicted age-adjusted incidence rate in total primary rhegmatogenous retinal detachment (RRD) and pseudophakic primary RRD and the attribution of pseudophakia to the total increase in total primary RRD.

	Total primary RRD			Pseudophakic primary RRD			
	Cases per 100 000 person-years						
	Predicted linear crude incidence rate			Predicted linear crude incidence rate			
Sex	2006	2021	IRD	2006	2021	IRD	Attribution of pseudophakia to the total increase (%)
Female	16.2	27.8	11.6	3.7	7.8	4.1	35 (4.1/11.6)
Male	25.9	49.2	23.3	6.7	14.7	7.9	34 (7.9/23.3)

Abbreviations: IRD, incidence rate difference; RRD, rhegmatogenous retinal detachment.

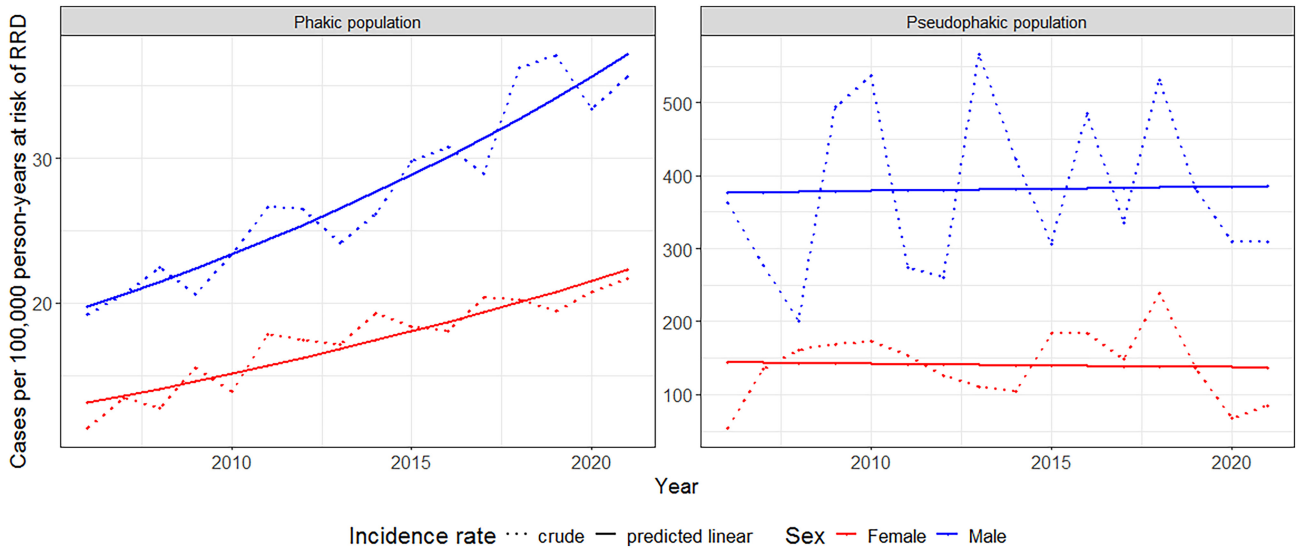

FIGURE 2 The crude and predicted annual incidence rate for phakic RRD in phakic individuals stratified by sex is shown on the left. The figure on the right shows the annual 1-year postoperative incidence rate of pseudophakic RRD within the pseudophakic population stratified by sex. Abbreviations: RRD, rhegmatogenous retinal detachment.

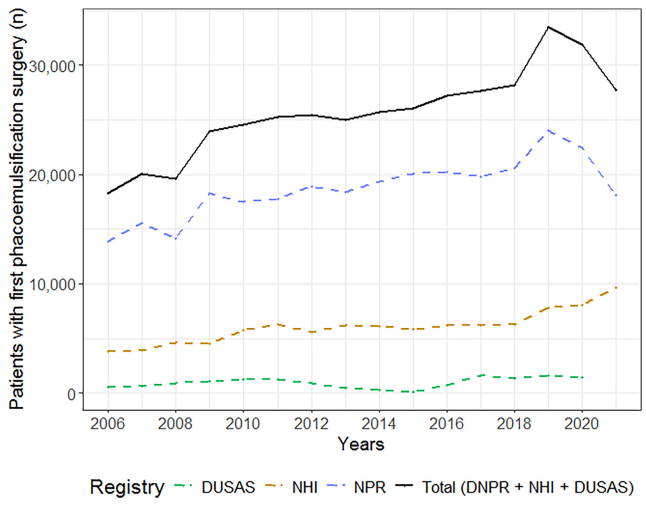

FIGURE 3 Total number of first phacoemulsification surgeries for age-related cataracts or ametropia in individuals 40 years of age or above from 1994, stratified by the source of registration. Abbreviations: DUSAS, the Health Authority's Registry of Danish patients treated at foreign hospitals and activity in specialist medical practices; NHI, National Health Insurance registry; NPR, Danish National Patient Registry.

(Hajari et al., 2014; Nielsen et al., 2020). In the present study, we found that this increase continued unabated in the population above 40 years of age until at least 2021 and that this increase was more pronounced in males than in females.

We found an increase in the crude and age and sex-adjusted incidence rates of both pseudophakic and phakic primary RRD in the entire Danish population. The largest proportion of the increase was driven by phRRDs, but after adjusting for registry misclassification, we estimated that 45% of the total increase in RRD could be attributed to the increase in pRRD. While the phRRD demonstrated the largest absolute increase in the entire population, the relative annual growth was more pronounced in the pRRDs than in the phRRDs. This trend was similarly observed in a Norwegian study, where the annual increase in pRRD cases was twice the rate observed in phakic RRD cases (Achour et al., 2022).

In this study, we examined the role of phacoemulsification surgery in the increased incidence rate of primary RRD in the Danish population. We have previously shown that phacoemulsification surgery

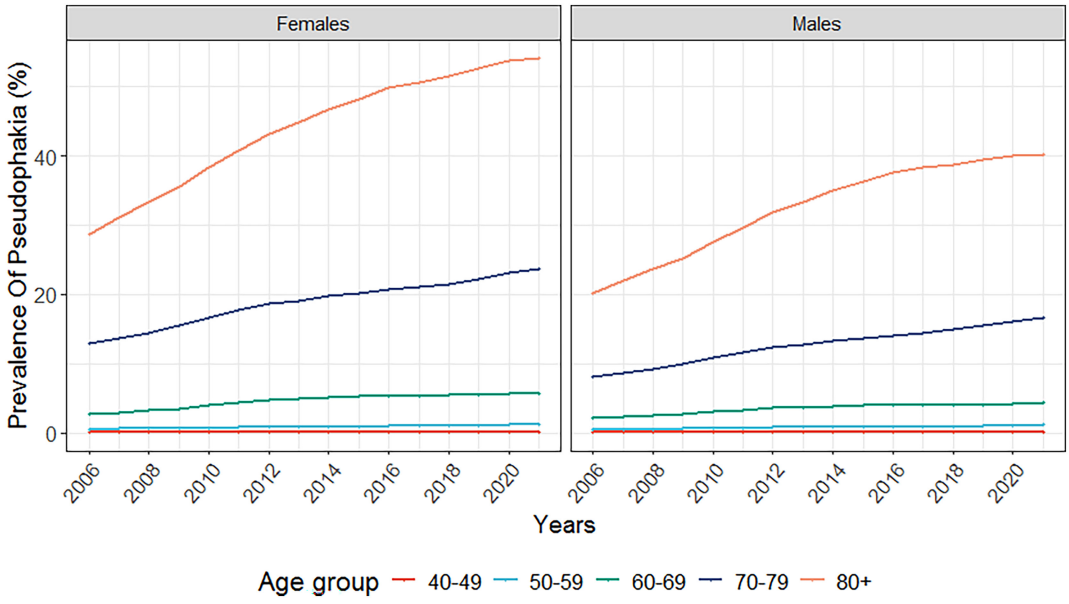

FIGURE 4 The prevalence of pseudophakia in at least one eye in the Danish population aged 40 years and above and at risk of pseudophakic rhegmatogenous retinal detachment from 2006 to 2022, stratified by sex and age.

increases the baseline risk of RRD by a factor of four and that this increased risk persists for at least 10 years (Bjerrum et al., 2013). Therefore, a larger pseudophakic population (Figure 4) results in an increase in the number of pRRDs in the population. The observed increase in the incidence rate of phRRDs could indicate a change in risk factors, for example myopia., which should also impact the number of pRRDs in the population (van Leeuwen et al., 2020). However, we found that the 1-year postoperative incidence of pRRD within the pseudophakic population remained stable throughout the entire study period (2006–2021, Figure 2). We believe that the observed increase in the number of pRRDs in the population is explained by the increase in the population at risk, namely the pseudophakic population. This is surprising, as it implies that the pseudophakic population could be uncoupled from the risk factors responsible for the rise in the incidence of RRDs in the phakic population. However, improved surgical equipment, decreasing rates of capsule complications and the adoption of simulation surgical training in phacoemulsification surgery might have contributed to masking such risk factors and resulted in a more modest increase in the number of pRRDs (Lundström et al., 2011; McCannel, 2015; Thomsen et al., 2017). Although the increase in the incidence rate of primary RRD was only noted in the phakic population and not in the pseudophakic population, the incidence rate of primary RRD was remarkably higher in pseudophakic individuals than the phakic individuals (Figure 2), which is consistent with our understanding (Bjerrum et al., 2013).

Within the phakic population at risk of primary RRD, we found a significant annual increase in the incidence rate of phakic RRD for both females and males, even after adjusting for age (Figure 2). The cause of the increased incidence of primary RRD in the phakic population remains unknown. Myopia is a known risk factor for RRD, and the prevalence of myopia in the Asian population has been reportedly rising over several decades (Morgan et al., 2021). European population studies have also recently found myopia to be on the rise (Holden et al., 2016; van Leeuwen et al., 2020; Williams et al., 2015). Thus, it has been suggested that the increase in phakic RRD could be due to the rise in myopia (van Leeuwen et al., 2020), yet Scandinavian and Danish population studies have not found an increase in the prevalence of myopia (Bro & Löfgren, 2023; Hagen et al., 2018; Hansen et al., 2021).

Another risk factor for RRD is ocular trauma, which occurs more frequently in younger males (Johansen et al., 1992; Laatikainen & Tolppanen, 1985; Poulsen et al., 2016; Vestergaard et al., 2015). We excluded individuals who had experienced any ocular trauma requiring surgery, such as the removal of intraocular foreign bodies and treatment for perforated lesions on the cornea and sclera (Table S1), as well as individuals under 40 years of age. However, as blunt traumas may not come under the care of medical professionals and minor traumas such as hyphaema are often treated in private clinics, both of these scenarios are likely to escape registration within the NPR. Therefore, we cannot draw definitive conclusions about the contribution of blunt ocular traumas and head traumas to the increase in the RRD incidence rate.

We found no significant increase in the 1-year incidence rate of pRRD in the pseudophakic population, yet our findings show that primary RRD occurred at an earlier age in the phakic population than in the pseudophakic population – 8.6 years earlier for females and 5.4 years earlier for males. If the prevalence of myopia did indeed begin to rise during our study period, this would likely have manifested as an increase in the phRRD incidence earlier than in the pseudophakic population. Therefore, we cannot rule out the possibility of myopia being part of the explanation for the observed time-dependence difference in RRD incidence between the phakic and pseudophakic populations in our study.

TABLE 4 Chart review of lens status in patients with primary RRD. (a) Represents the patients considered, per registry, as being pseudophakic but reevaluated after chart review. (b) Represents the patients considered, per registry, as being phakic but reevaluated after chart review.

As per registry				Chart review		Calculations		
Sex	Total number of patients	Number of RRD patients with certain lens status	Number of RRD patients with uncertain lens status	Sample size	Found wrong	Miscoded/sample size (error %)	Estimated number of wrongs	Corrected total
(a) Patients we have considered pseudophakic								
Female	**1283**	**1211**	**72**	**58**	**3**	**5%**	**4**	**1647**
		• 959 Bilateral phacoemulsification surgery	• 72 Unknown lateralisation					
		• 185 Unilateral surgery						
		• 67 Intraocular lens						
Male	**2259**	**2128**	**131**	**114**	**7**	**6%**	**8**	**3023**
		• 1507 Bilateral phacoemulsification surgery	• 131 Unknown lateralisation					
		• 472 Uni lateral surgery						
		• 149 Intraocular lens						
Total	**3542**	**3339**	**203**	**172**	**10**	**6%**	**12**	**4657**
(b) Patients we have considered phakic								
Female	**3716**	**1378**	**2338**					**3352**
		• 493 Bilateral phacoemulsification surgery after RRD-repair surgery	• 35 Phacoemulsification surgery in fellow eye before RRD	27	29	69%	41	
		• 885 Unilateral same-sided phacoemulsification surgery after RRD repair surgery	• 2338 No phacoemulsification surgery before RRD	486	69	14%	327	
Male	**5780**	**1955**	**3825**					**5016**
		• 619 Bilateral phacoemulsification surgery after RRD-repair surgery	• 63 Phacoemulsification surgery in fellow eye before RRD	60	52	68%	59	
		• 1336 Unilateral same-sided phacoemulsification surgery after RRD repair surgery	• 3825 No phacoemulsification surgery before RRD	648	123	19%	714	
Total	**9496**	**3333**	**6163**					**8381**
			• 98 Phacoemulsification surgery in fellow eye before RRD	87	59	68%	100	
			• 6065 No phacoemulsification surgery before RRD	1134	192	17%	1026	

Abbreviation: RRD, rhegmatogenous retinal detachment.

To investigate potential temporal changes (from 2006 to 2021) in the incidence of pRRD in the pseudophakic population, we limited the follow-up time after phacoemulsification surgery to one year (Figure 2). This approach was used to ensure identical risk periods across different years in which the phacoemulsification surgery was performed, due to the non-linear risk of pRRD following phacoemulsification surgery (Bjerrum et al., 2013; Boberg-Ans et al., 2003; Erie et al., 2006). Restricting the follow-up time to only one year introduced a caveat to our study, as the development of risk after the first postoperative year might have differed over the study period.

One of the strengths of this study was our ability to access a large dataset of the entire Danish population over a 25-year period. We also consider that the risk of selection bias in the outcomes was low because all Danish residents have access to free medical treatment and the vast majority of vitreoretinal surgeries, and virtually all RRD repair surgeries, are carried out in public hospitals, which means that they are registered (otherwise hospitals would not be reimbursed). The presence of a compensation system for hospitals that is based on correct registration in the nationwide register is another strength. This system incentivises hospitals to maintain accurate and up-to-date registration, resulting in reliable and high-quality data for the study. Furthermore, we validated the registry data by conducting a chart review.

The main limitation in this study was that phacoemulsification surgery was incompletely registered. We addressed this issue through a comprehensive nationwide chart review, where we were able to estimate the true distribution of phakic and pseudophakic primary RRD. By correcting misclassified phRRDs, which were actually pseudophakic, we found that the contribution of pseudophakia to the overall rise in the RRD incidence rate within the entire population increased by 10 percentage points, from 35% to 45%. The proportion of pRRD increased from 27.0% to 35.7%, which is consistent with a Danish study based on data from a subunit database, where 37.2% of RRDs were pseudophakic (Poulsen et al., 2016). We observed no trend indicating a decrease in misclassification over the years, which is a little surprising given the mandatory registration of all intraocular surgeries that have been performed in private and public hospitals in Denmark since 2004, with the exception of registrations in NHI, which are not included in this law (Retsinformation, 2003). However, as with any sample, uncertainties existed regarding the estimated lens status of RRD cases, as the chart review represents only a sample of the entire population. We addressed this issue by ensuring that sample sizes for each subcategory had a margin of error of 4% or less. This implies a 95% likelihood that the true value falls within a range encompassing 4 percentage points above and below the reported result.

Another limitation of our registry-based research was the possibility of incorrect or missing registration of procedures and diagnosis codes and the lack of laterality. To overcome the problems with the lack of laterality information, we only included and excluded on an individual level. In terms of outcome validity, 96% of primary RRD repair surgeries, as per the registry, were indeed true primary RRD repairs. This reflects other validation studies on the NPR (Schmidt et al., 2015) and a previous validation study of retinal detachment repair surgery in Denmark (Hajari et al., 2014). Incorporating potential non-rhegmatogenous diagnostic codes, such as retinoschisis, exudative retinal detachment and retinal tear, poses a limitation in our study as it could have led to the inclusion of non-rhegmatogenous cases. The rationale for including these diagnostic codes was that these conditions should not, unless they include a rhegmatogenous component, be treated with a procedure of retinal detachment repair; thus, leaving out these codes could also have led to an underestimation of the incidence rate of primary RRD. Only 8 out of 987 cases in our chart review turned out to be RRD due to retinoschisis, exudative retinal detachment and retinal tear based on these 'non-RRD' diagnose codes (Figure S1).

As no data were available on individuals from before 1996, it could be possible that we identified individuals as primary RRD, even if they were re-detachment cases. However, since the increased risk of re-detachment is primarily limited to the initial two years following RRD surgery (Hajari et al., 2014) and given our long lead time of 10 years, retinal detachment cases from before 1996 had a negligible influence on the incidence rate of RRD from 2006 to 2021. Likewise, cataract surgery could have been performed prior to 1996, but by starting the study period 10 years after 1996, we know that they are at least past the 10-year period where the risk of pRRD is increased following phacoemulsification surgery (Bjerrum et al., 2013).

5 | CONCLUSION

In this nationwide register-based cohort study, including 16 years of follow-up, we found an increase in the incidence rate of primary RRD, with an increase in the pseudophakic population accounting for 45% of this rise. The increase in the number of pRRDs seems to be driven by the increase in the size of the pseudophakic population. The largest increase in the incidence rate of primary RRD was observed in the phakic population. Although myopia is a known risk factor for RRD and may contribute to an increase in phRRDs, we lack evidence for increased myopia in Denmark, and we are sceptical that myopia could have exclusively impacted the phakic population and not the pseudophakic population, as evidenced by the 1-year incidence rate of pRRD having remained constant throughout the study period. Further research determining the underlying causes of the rise in the incidence of primary RRD is of utmost importance.

ACKNOWLEDGEMENTS

We would like to thank 'Fight for Sight', Helsefonden, Candys Foundation, Synoptik Foundation and RH-OUH Research Foundation for funding the study. A special thanks also goes to Brice Ozenne from the Biostatistics Department at Copenhagen University for his help and support in the statistical analysis.

ORCID

Birgitte Romme Nielsen https://orcid.org/0000-0001-9840-8036
Toke Bek https://orcid.org/0000-0002-0409-2534
Benjamin Sommer Thinggaard https://orcid.org/0000-0002-3450-3568
Jakob Grauslund https://orcid.org/0000-0001-5019-0736

REFERENCES

Achour, H., Thomseth, V.M., Kvaløy, J.T., Krohn, J., Utheim, T.P. & Forsaa, V.A. (2022) Substantial increase in the incidence of rhegmatogenous retinal detachment in Western Norway over 20 years [article]. *Acta Ophthalmologica*, 100(7), 763–768. Available from: https://doi.org/10.1111/aos.15119

Alio, J.L., Grzybowski, A., El Aswad, A. & Romaniuk, D. (2014) Refractive lens exchange. *Survey of Ophthalmology*, 59(6), 579–598. Available from: https://doi.org/10.1016/j.survophthal.2014.04.004

Bjerrum, S.S., Mikkelsen, K.L. & La Cour, M. (2013) Risk of pseudophakic retinal detachment in 202 226 patients using the fellow nonoperated eye as reference. *Ophthalmology*, 120(12), 2573–2579. Available from: https://doi.org/10.1016/j.ophtha.2013.07.045

Boberg-Ans, G., Villumsen, J. & Henning, V. (2003) Retinal detachment after phacoemulsification cataract extraction. *Journal of Cataract and Refractive Surgery*, 29(7), 1333–1338. Available from: https://doi.org/10.1016/S0886-3350(03)00057-9

Bro, T. & Löfgren, S. (2023) Relatively stable prevalence of myopia among Swedish children aged 4 to 7 years between 2015 and 2020. *Optometry and Vision Science*, 100(1), 91–95. Available from: https://doi.org/10.1097/OPX.0000000000001972

Chen, S.N., Lian, I.B. & Wei, Y.J. (2016) Epidemiology and clinical characteristics of rhegmatogenous retinal detachment in Taiwan. *British Journal of Ophthalmology*, 100(9), 1216–1220. Available from: https://doi.org/10.1136/bjophthalmol-2015-307481

El-Abiary, M., Shams, F., Goudie, C. & Yorston, D. (2023) The Scottish RD survey 10 years on: the increasing incidence of retinal detachments. *Eye (Basingstoke)*, 37, 1320–1324. Available from: https://doi.org/10.1038/s41433-022-02123-1

Erie, J.C., Raecker, M.A., Baratz, K.H., Schleck, C.D., Burke, J.P. & Robertson, D.M. (2006) Risk of retinal detachment after cataract extraction, 1980–2004: a population-based study. *Ophthalmology*, 113(11), 2026–2032. Available from: https://doi.org/10.1016/J.OPHTHA.2006.05.054

Hagen, L.A., Gjelle, J.V.B., Arnegard, S., Pedersen, H.R., Gilson, S.J. & Baraas, R.C. (2018) Prevalence and possible factors of myopia in Norwegian adolescents. *Scientific Reports*, 8(1), 13479. Available from: https://doi.org/10.1038/S41598-018-31790-Y

Hajari, J.N., Bjerrum, S.S., Christensen, U., Kiilgaard, J.F., Bek, T. & La Cour, M. (2014) A nationwide study on the incidence of rhegmatogenous retinal detachment in Denmark, with emphasis on the risk of the fellow eye. *Retina*, 34(8), 1658–1665. Available from: https://doi.org/10.1097/IAE.0000000000000104

Hansen, M.H., Hvid-Hansen, A., Jacobsen, N. & Kessel, L. (2021) Myopia prevalence in Denmark – a review of 140 years of myopia research. *Acta Ophthalmologica*, 99(2), 118–127. Available from: https://doi.org/10.1111/AOS.14562

Høeg, T.B., Ellervik, C., Buch, H., La Cour, M., Klemp, K., Kvetny, J. et al. (2016) Danish rural eye study: epidemiology of adult visual impairment. *Ophthalmic Epidemiology*, 23(1), 53–62. Available from: https://doi.org/10.3109/09286586.2015.1066396

Holden, B.A., Fricke, T.R., Wilson, D.A., Jong, M., Naidoo, K.S., Sankaridurg, P. et al. (2016) Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology*, 123(5), 1036–1042. Available from: https://doi.org/10.1016/j.ophtha.2016.01.006

Johansen, J., Theodorsen, F.P. & Corydon, L. (1992) Visual outcome following complicated extracapsular cataract extraction. *Journal of Cataract and Refractive Surgery*, 18(6), 577–581. Available from: https://doi.org/10.1016/S0886-3350(13)80446-4

Laatikainen, L. & Tolppanen, E.-M. (1985) Characteristics of rhegmatogenous retinal detachment. *Acta Ophthalmologica*, 63(2), 146–154. Available from: https://doi.org/10.1111/J.1755-3768.1985.TB01527.X

Lundström, M., Behndig, A., Kugelberg, M., Montan, P., Stenevi, U. & Thorburn, W. (2011) Decreasing rate of capsule complications in cataract surgery: eight-year study of incidence, risk factors, and data validity by the Swedish National Cataract Register. *Journal of Cataract and Refractive Surgery*, 37(10), 1762–1767. Available from: https://doi.org/10.1016/J.JCRS.2011.05.022

Lundström, M., Goh, P.P., Henry, Y., Salowi, M.A., Barry, P., Manning, S. et al. (2015) The changing pattern of cataract surgery indications: a 5-year study of 2 cataract surgery databases. *Ophthalmology*, 122(1), 31–38. Available from: https://doi.org/10.1016/j.ophtha.2014.07.047

Lundström, M., Stenevi, U. & Thorburn, W. (2001) Age-related utilisation of cataract surgery in Sweden during 1992–1999. A retrospective study of cataract surgery rate in one-year age groups based on the Swedish National Cataract Register. *Acta Ophthalmologica Scandinavica*, 79(4), 342–349. Available from: https://doi.org/10.1034/j.1600-0420.2001.079004342.x

McCannel, C.A. (2015) Simulation surgical teaching in ophthalmology. *Ophthalmology*, 122(12), 2371–2372. Available from: https://doi.org/10.1016/j.ophtha.2015.08.036

Mitry, D., Charteris, D.G., Yorston, D., Rehman Siddiqui, M.A., Campbell, H., Murphy, A.L. et al. (2010) The epidemiology and socioeconomic associations of retinal detachment in Scotland: a two-year prospective population-based study. *Investigative Ophthalmology and Visual Science*, 51(10), 4963–4968. Available from: https://doi.org/10.1167/iovs.10-5400

Morgan, I.G., Wu, P.C., Ostrin, L.A., Tideman, J.W., Yam, J.C., Lan, W. et al. (2021) IMI risk factors for myopia. *Investigative Ophthalmology and Visual Science*, 62(5), 3. Available from: https://doi.org/10.1167/iovs.62.5.3

National Cancer Institute. (2006) Calculating Age-adjusted Rates. *Surveillance, Epidemiology, and End Results Program*. https://seer.cancer.gov/seerstat/tutorials/aarates/step3.html

Nielsen, B.R., Alberti, M., Bjerrum, S.S. & la Cour, M. (2020) The incidence of rhegmatogenous retinal detachment is increasing. *Acta Ophthalmologica*, 98(6), 603–606. Available from: https://doi.org/10.1111/aos.14380

Pastor Jimeno, J.C., Fernández, I., De La Rodríguez Rúa, E., Coco, R., Sanabria-Ruiz Colmenares, M.R., Sánchez-Chicharro, D. et al. (2008) Surgical outcomes for primary rhegmatogenous retinal detachments in phakic and pseudophakic patients: the Retina 1 Project–report 2. *The British Journal of Ophthalmology*, 92(3), 378–382. Available from: https://doi.org/10.1136/BJO.2007.129437

Poulsen, C.D., Peto, T., Grauslund, J. & Green, A. (2016) Epidemiologic characteristics of retinal detachment surgery at a specialized unit in Denmark. *Acta Ophthalmologica*, 94(6), 548–555. Available from: https://doi.org/10.1111/aos.13113

Retsinformation. (2003) Bekendtgørelse om lægers anmeldelse til Sundhedsstyrelsens Landspatientregister af patienter behandlet på private sygehuse eller klinikker. *BEK Nr 986 Af 08/12/2003*. https://www.retsinformation.dk/eli/lta/2003/986

Schmidt, M., Pedersen, L. & Sørensen, H.T. (2014) The Danish civil registration system as a tool in epidemiology. *European Journal of Epidemiology*, 29(8), 541–549. Available from: https://doi.org/10.1007/S10654-014-9930-3

Schmidt, M., Schmidt, S.A.J., Sandegaard, J.L., Ehrenstein, V., Pedersen, L. & Sørensen, H.T. (2015) The Danish National Patient Registry: a review of content, data quality, and research potential. *Clinical Epidemiology*, 7, 449–490. Available from: https://doi.org/10.2147/CLEP.S91125

Solborg Bjerrum, S., Kiilgaard, J.F., Mikkelsen, K.L. & La Cour, M. (2013) Outsourced cataract surgery and postoperative endophthalmitis. *Acta Ophthalmologica*, 91(8), 701–708. Available from: https://doi.org/10.1111/aos.12279

Solborg Bjerrum, S., Mikkelsen, K.L. & La Cour, M. (2015) Epidemiology of 411 140 cataract operations performed in public hospitals and private hospitals/clinics in Denmark between 2004 and 2012. *Acta Ophthalmologica*, 93(1), 16–23. Available from: https://doi.org/10.1111/aos.12576

Thomsen, A.S.S., Bach-Holm, D., Kjærbo, H., Højgaard-Olsen, K., Subhi, Y., Saleh, G.M. et al. (2017) Operating room performance

improves after proficiency-based virtual reality cataract surgery training. *Ophthalmology*, 124(4), 524–531. Available from: https://doi.org/10.1016/j.ophtha.2016.11.015

van Leeuwen, R., Haarman, A.E.G., van de Put, M.A.J., Klaver, C.C.W. & Los, L.I. (2020) Association of rhegmatogenous retinal detachment incidence with myopia prevalence in The Netherlands. *JAMA Ophthalmology*, 1–8, 85–92. Available from: https://doi.org/10.1001/jamaophthalmol.2020.5114

Vestergaard, J.P., Søltoft, A.M., Aasholm, V.R. & Grauslund, J. (2015) The five-year incidence of open globe eye injuries at Odense University Hospital, Denmark. *Acta Ophthalmologica*, 93(8), e679–e680. Available from: https://doi.org/10.1111/aos.12742

Williams, K.M., Bertelsen, G., Cumberland, P., Wolfram, C., Verhoeven, V.J.M., Anastasopoulos, E. et al. (2015) Increasing prevalence of myopia in Europe and the impact of education. *Ophthalmology*, 122(7), 1489–1497. Available from: https://doi.org/10.1016/j.ophtha.2015.03.018

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Nielsen, B.R., Alberti, M., Høgild, M.L., Bek, T., Thinggaard, B.S., Grauslund, J. et al. (2024) The role of phacoemulsification surgery in the incidence rate of rhegmatogenous retinal detachment. *Acta Ophthalmologica*, 102, 931–941. Available from: https://doi.org/10.1111/aos.16723