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Adherence to vaccination guidelines of patients with complete splenectomy in Norway, 2008–2020

Saima Orangzeb, Sara Viksmoen Watle, Dominique A. Caugant *

Department of Community Medicine and Global Health, Faculty of Medicine, University of Oslo, Oslo, Norway
Division for Infection Control, Norwegian Institute of Public Health, Oslo, Norway

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ABSTRACT

The spleen is responsible for blood filtration and mounting an immune response against pathogens. In some people the spleen must be surgically removed because of traumatic events or oncological and hematological conditions. These patients are at higher risk of developing diseases caused by encapsulated bacteria throughout their lives. Thus, immunisations are advised for splenectomised persons to prevent infection caused by *Streptococcus pneumoniae*, *Neisseria meningitidis* and *Haemophilus influenzae* type b (Hib). This study assessed vaccination coverage (VC) among Norwegian patients with surgical asplenia. Using the Nomesco Classification of Surgical Procedures codes, patient information (age, sex, date of initial diagnosis and date of surgery) was acquired from the Norwegian Patient Registry. The National Immunization Register provided information on vaccination status and data of any subsequent invasive bacterial infections were obtained from the Norwegian Surveillance System for Communicable Diseases. From the total population of Norway, 3155 patients who had undergone complete splenectomy were identified. Of these, 914 (29.0%) had received at least one dose of pneumococcal conjugate vaccine (PCV), 1324 (42.0%) at least one dose of pneumococcal polysaccharide vaccine and 589 (18.7%) had received both. Only 4.2% of the patients had received two doses of a meningococcal ACWY conjugate vaccine, while 8.0% of 1467 patients splenectomised after 2014 had received at least two doses of a serogroup B meningococcal vaccine. The VC for Hib was 18.7%. Nearly all splenectomised children under the age of 10 were vaccinated with Hib and PCV as these vaccines are included in the childhood immunisation program. For all vaccines, VC decreased with age. Twenty-nine invasive bacterial infections were registered post-splenectomy in 25 patients. Vaccination according to national recommendations could have prevented at least 8 (28%) of these infections. Our study showed that efforts are required to increase VC of splenectomised individuals in Norway.

1. Introduction

The spleen is a crucial organ in that it filters the blood, eliminates any damaged or old blood cells, and regulates the quantity of white and red blood cells as well as platelets. Its other function is in the development of immune responses against pathogens through both the innate and adaptative immune systems. Some individuals are born without a spleen (congenital asplenia), while others might require its removal due to disease or damage. The most common cause of asplenia is surgical removal of the spleen following trauma, such as a blow to the abdomen, a car or a sports accident, or broken ribs [1]. Medical conditions, including blood disorders, such as sickle cell disease, cancer and various liver and gastrointestinal diseases may lead to hyposplenia or functional asplenia requiring removal of the spleen [2].

Although many of the spleen's tasks can be performed by other organs, such as the liver, encapsulated pathogens are normally opsonized by antibodies and subsequently phagocytosed by specialised macrophages in the spleen. Asplenia causes the absence of these specialized macrophages, which increases the likelihood of developing fulminant sepsis when exposed to these pathogens [3,4]. While the syndrome, called overwhelming post-splenectomy infection (OPSI) is rare, the mortality rate of OPSI is high, ranging from 40% to 70% [5]. The risk of sepsis is much higher in the first three years after the surgery, but OPSI can occur up to 50 years after splenectomy. *Streptococcus pneumoniae* (pneumococci), *Neisseria meningitidis* (meningococci) and *Haemophilus influenzae* type b (Hib) are the most common etiological agents

* Corresponding author at: Norwegian Institute of Public Health, P.O. Box 222 Skøyen, NO-0213 Oslo, Norway.
E-mail address: dominique.caugant@fhi.no (D.A. Caugant).

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linked to significant illness in these patients [6–8], with *S. pneumoniae* causing 50–90% of these infections [6].

To reduce post-splenectomy infections, patients are made aware of the dangers of such infections and encouraged to adhere to precautionary measures. Vaccination against *S. pneumoniae, N. meningitidis,* and Hib can help prevent OPSI. Thus, it is recommended that all asplenic individuals should receive pneumococcal, meningococcal and Hib vaccines to decrease the risk of post-splenectomy infections.

In Norway the Hib vaccine was introduced in the childhood vaccination program in 1992. The 23-valent pneumococcal polysaccharide vaccine (PPV23) was licensed in Norway in 1983 and generally recommended for the elderly and children over 2 years of age with underlying medical conditions. Pneumococcal conjugate vaccines (PCVs) were introduced in the childhood vaccination program in 2006 (PCV7) and PCV7 was replaced by PCV13 in 2011. The tetravalent conjugate meningococcal vaccines against serogroups A, C, W and Y (MCV4) have been available in Norway since 2010 (MenACWY-CRM) and 2012 (MenACWY-TT), while serogroup B meningococcal vaccines have been available since 2014 (four-component meningococcus B vaccine, 4CMenB) and 2017 (meningococcus B Factor H-binding protein vaccine, MenB-FHbp). Meningococcal vaccines are not included in the childhood vaccination program, but are recommended for risk groups, including individuals who are missing spleen function [9]. Vaccine acceptance is high in Norway, with 92–97% of children vaccinated according to the national immunisation programme (NIP) and over 90% of individuals over 65 years vaccinated with three doses of a COVID-19 vaccine [10,11].

Regarding vaccination of splenectomised patients, the Norwegian Institute of Public Health (NIPH) has established the following guidelines: 1) PCV in addition to the 23-valent polysaccharide vaccine (PPV23) against pneumococci; 2) MCV4 and a meningococcal B protein vaccine; and 3) Hib conjugate vaccine. Since the incidence of Hib is currently low in Norway [12] and vaccination has been provided through the NIP since 1992, Hib vaccination has a lower priority than vaccination against pneumococci and meningococci [13]. Vaccination should be completed before surgery if possible, or initiated before discharge from the hospital, and completed as soon as possible according to national recommendations [13].

The aim of this study was to evaluate the vaccination coverage (VC) of splenectomised patients in Norway, following the advised vaccination protocol from the NIPH, and to determine the prevalence of invasive disease caused by these three bacterial pathogens among splenectomised patients in Norway.

2. Methods

2.1. Data sources

This retrospective study included all patients who had undergone total splenectomy in Norway between January 1, 2008 and December 31, 2020. Data for the study came from the National Patient Register (NPR), the Norwegian Immunisation Registry (SYSVAK) and the Norwegian Surveillance System for Communicable Diseases (MSIS). NPR provided a list of all patients registered with the Nomesco Classification of Surgical Procedures codes JMA10 (transabdominal splenectomy), JMA11 (laparoscopic splenectomy), and JMA20 (transthoracal splenectomy) during the study period, together with patient information (age, sex, date of initial diagnosis and date of surgery). Using the unique personal identification number of the individuals in Norway, information on vaccination (administration date and product) against pneumococci, meningococci and Hib was obtained for the patients from SYSVAK and data on any subsequent invasive bacterial infections were obtained from MSIS.

2.2. Data analysis

Data management and statistical analyses were performed using the Stata SE 17. Incidence rate of splenectomy per 100,000 person-years was calculated as: number of splenectomised patients / population size /13 $\times$ 100,000. The 2020 population size in the different age groups and in total was used. Vaccination status was determined using the binary variable of yes and no vaccination for each type of vaccine, as well as for multiple doses where the intervals between doses followed national recommendations. VC for each type of vaccine was calculated as: number of vaccinated patients / number of patients with complete splenectomy $\times$ 100. For each patient and vaccine, the time of vaccination was related to the time when splenectomy was performed. Pearson's correlation coefficients between age of the patients and vaccine coverage were calculated for each vaccine.

2.3. Ethical clearance

The project obtained approval from the Norwegian Regional Committees for Medical and Health Research (REK). Only de-identified individual data were provided to the research group.

3. Results

3.1. Patients

In total, 3,218 patients with complete splenectomy were registered between 2008 and 2020 in NPR. Sixty-three patients were excluded from the analyses as they had been removed from the National Population Registry within 8 weeks of splenectomy due to various reasons, such as death, emigration, expired birth number, and unregistered person. Among the 3155 remaining patients, 49.4% (N = 1558) were males and 50.6% (N = 1597) females. The average age was 57.9 years (SD = 18.5), with 54.3% patients (N = 1712) being over 60 years of age (Table 1). The International Classification of Diseases 10th Revision (ICD-10) codes were available for 947 (30.0%) patients (Table 2). Unspecified injury of the spleen (S36.0) was the most frequently recorded diagnosis (41.1%), followed by hyposplenism (19.2%) and splenomegaly (16.7%). S36.0 was significantly more frequent among males than among females in all age-groups, but especially so in the 11 to 30 years old (chi-square 31.9; $p < 0.0001$).

3.2. VC with pneumococcal vaccines

Among the 3,155 patients who were kept within the NPR at least 8 weeks after complete splenectomy, 28.9% had received a PCV, 42.0% had been vaccinated with PPV23, and 18.7% had received both PCV and PPV23 (Table 3). Almost all the individuals who were vaccinated with either PCV or PCV+PPV23 received their first vaccine dose within 8 weeks of splenectomy, whereas less than half of the patients receiving PPV23 alone were vaccinated within this time limit (Fig. 1).

Children in the age group 1–10 years had the highest VC for PCV (97.8%), PPV23 (80.9%) and consequently both PCV+PPV23 (78.7%) (Table 3). VC decreased with increasing age (Pearson's correlation −0.61, −0.58 and −0.66 for PCV, PPV23 and PCV+PPV23, respectively). While less than 30% of the individuals older than 10 had received PCV, the coverage of PPV23 in this age group was 41.5%. Excluding the 11–20-year-olds who probably had received PCV in

Table 1
Age at diagnosis and gender of 3,155 splenectomised patients in Norway, 2008–2020.

	Males		Females	
Age at diagnosis	Number	Incidence rate	Number	Incidence rate
0–10	34	0.8	18	0.5
11–20	80	1.9	53	1.3
21–30	93	2.0	78	1.7
31–40	90	1.8	125	2.7
41–50	148	3.1	151	3.3
51–60	270	5.8	303	6.8
61–70	415	10.9	440	11.6
71–80	360	13.1	339	11.6
>80	68	5.8	90	4.9
Total	**1,558**	**4.4**	**1,597**	**4.6**

Table 2
Diagnosis and age at diagnosis of 947 splenectomised patients in Norway, 2008–2020.

Diagnosis	No. of patients	Age-groups in years									
		0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	>90
Hyposplenism	182	0	19	17	13	13	38	48	27	7	0
Hypersplenism	26	2	6	1	2	3	4	5	1	2	0
Chronic congestive splenomegaly	8	2	2	1	1	1	1	0	0	0	0
Abscess of spleen	23	0	1	1	2	2	6	4	5	2	0
Cyst of spleen	32	0	3	6	8	3	4	3	5	0	0
Infarction of spleen	76	1	6	8	6	15	7	17	13	3	0
Other spleen diseases	50	1	4	6	4	9	6	14	5	1	0
Rupture of spleen	3	0	0	0	0	1	0	2	0	0	0
Splenomegaly	158	9	20	14	14	18	16	47	18	2	0
Injury of spleen	389	4	42	46	39	44	58	73	63	19	1

Table 3
Vaccination coverage (%) of recommended vaccines among 3,155 splenectomised patients according to age groups in Norway, 2008–2020.

Age group (years)	Pneumococcal vaccines[†]			MCV4		MenB			Hib
	PCV	PPV23	PCV+PPV23	≥1 dose	≥2 doses	≥1 dose	≥2 doses	≥3 doses	≥1 dose
1–10	97.8	80.9	78.7	66.0	55.3	38.3	38.3	29.8	97.8
11–20	37.0	42.5	37.0	40.2	14.2	33.1	26.0	11.8	37.8
21–30	31.6	38.6	20.5	12.3	7.0	18.1	8.8	2.3	25.7
31–40	30.4	39.1	12.1	9.7	4.8	9.2	2.9	0.5	19.8
41–50	33.1	44.7	9.9	14.8	4.6	6.3	3.5	1.4	23.6
51–60	28.0	39.6	21.4	10.3	2.2	3.1	0.9	0.2	14.8
61–70	28.4	49.0	19.5	9.5	2.7	4.7	2.9	0.6	16.5
71–80	25.6	40.0	15.3	9.4	2.12	3.7	2.4	0.3	13.4
81–90	15.6	18.4	12.4	5.9	2.1	2.2	1.1	0.0	8.6
≥ 91	12.5	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	29.0	42.0	18.7	12.1	4.2	6.8	4.2	1.5	18.7

PCV pneumococcal conjugate vaccine; PPV23 23-valent pneumococcal polysaccharide vaccine; MCV4 meningococcal quadrivalent conjugate vaccine; MenB serogroup B meningococcal vaccine; Hib *H. influenzae* type b conjugate vaccine.
[†] Vaccinated with one or more dose of pneumococcal vaccines.

the childhood immunisation program, only 16.9% of the adult splenectomised patients had received both PCV and PPV23.

3.3. VC with meningococcal quadrivalent conjugate vaccine (MCV4)

Among the 3,155 splenectomised patients, 12.1% had received ≥ 1 dose MCV4 vaccine and 4.2% had received two or more doses, with at least an 8-week interval between the first and the second dose, as recommended (Table 3). Most patients (85.3%) received the first vaccine dose within 8 weeks of splenectomy, as recommended by NIPH. The age-group 1–10 years had the highest VC (66.0%) for the MCV4 vaccines. VC of ≥2 doses MCV4 vaccines was 55.3%. Almost all the patients in this age group received the first vaccine dose within the recommended timeline (Fig. 1). There was a decrease in VC of MCV4 vaccines with age (Pearson's correlation −0.64 and −0.55 for one and two doses, respectively; Table 3).

3.4. VC with serogroup B vaccines

Among the 3,155 patients 6.8%, 4.2% and 1.5% had received one, two or three doses of a MenB vaccine within the recommended timeline (Table 3). However, as serogroup B meningococcal vaccines were first available in Norway in the fall 2014, the VC calculations were performed also only for the 1,467 patients who had splenectomy after December 2014. Among them 13.1% received ≥ 1 dose serogroup B vaccine and 8.0% received ≥ 2 doses with at least an 8-week interval between the first and the second dose. Most patients received the first vaccine dose within 8 weeks of splenectomy (Fig. 1). The age-group 1–10 years had the highest VC with 15 of the 16 patients in that age-group (93.8%) having

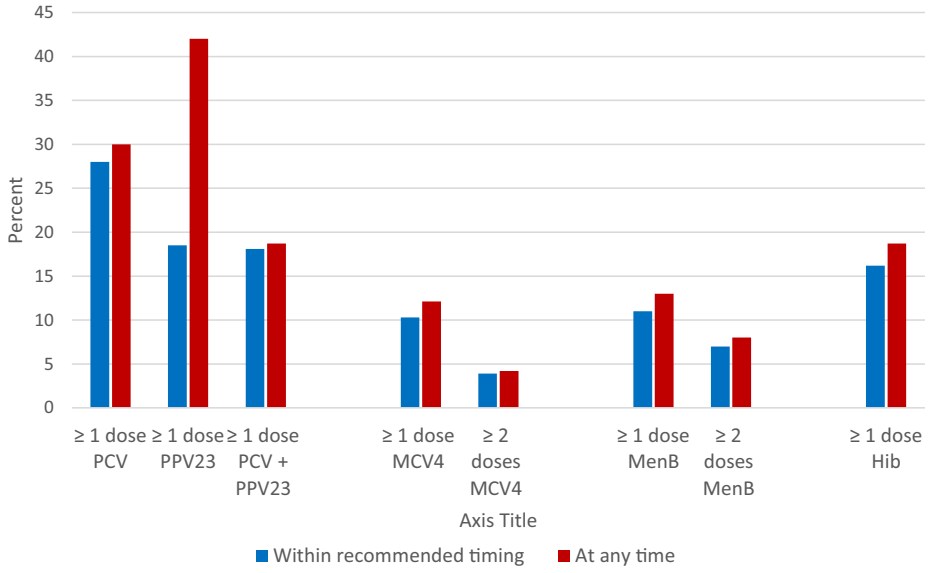

Fig. 1. Vaccination coverage with pneumococcal, meningococcal and Hib vaccines with and without reference to timeline of 8 weeks from splenectomy. PCV pneumococcal conjugate vaccine; 23-valent pneumococcal polysaccharide vaccine; MCV4 meningococcal quadrivalent conjugate vaccine; MenB serogroup B meningococcal vaccine; Hib *H. influenzae* type b conjugate vaccine.

received ≥2 doses and 81.3% having received ≥3 doses. VC of serogroup B vaccines decreased sharply with increase in age, especially after the age of 20 (Pearson's correlation −0.68, −0.60 and −0.48 for one, two and three doses, respectively).

3.5. VC with Hib vaccine

Among the 3,155 splenectomised patients only 18.7% had received at least one dose of Hib (Table 3) and 16.2% were vaccinated within the recommended timeline (Fig. 1). In the age-group 1–10 VC was 97.8%, but coverage declined already quite significantly in the 11 to 20 years olds (37.8%). The Pearson's correlation coefficient between age at splenectomy and Hib vaccination status was −0.72.

3.6. Invasive disease episodes

In our study population 25 patients experienced invasive disease episodes with pneumococci, meningococci, or Hib after splenectomy that were recorded in MSIS. Among these, 13 patients had invasive disease within 24 months of splenectomy. One of the 25 patients had meningococcal meningitis (serogroup Y) in 2010 and one patient had an invasive infection with *H. influenzae* (unknown serotype). The remaining 23 patients had pneumococcal infections, two of them twice (one with serotype 35F both times and one with first an unknown serotype and then a serotype 23A isolate) and one three times (two unknown serotype and the last one serotype 15A). Seven of the 23 patients (30.4%) with pneumococcal infections were infected with vaccine preventable strains, and none of them were vaccinated with pneumococcal vaccines (Table 4). The pneumococcal strains that were isolated from the three patients who were vaccinated were either of unknown serotype or were not vaccine preventable.

4. Discussion

This study showed that most splenectomised children under the age of 10 are vaccinated according to the NIPH recommendation. However, for all vaccines VC decreased dramatically with the age of the patients. Among patients above 20 years old, less than 1 in 4 were fully vaccinated against pneumococcal disease (PCV+PPV23) and less than 1 in 10 against meningococcal disease (2 doses of MCV4 and at least 2 doses of a serogroup B vaccine) according to national recommendations. The rate of post-splenectomy invasive infections with pneumococci, meningococci or Hib during the study period was 0.9% (29 events). There were no vaccine failure cases among the vaccinated patients, but almost one-third of the invasive infections in unvaccinated patients could probably have been prevented with vaccination.

To the best of our knowledge, this is the first registry-based study to evaluate vaccination rates among Norwegian patients who have had complete splenectomy. The strength of our study is that it includes all splenectomised patients from the entire Norwegian population registered in NPR between 2008 (the year of NPR inception in its present form) and 2020. To ensure that no patients were overlooked, we used both primary and secondary diagnoses. The personal identification number was used to connect information between registries. This number is unique for each person and accompanies the individual throughout its entire life. This reduces the possibility of over-inclusion when working with data from various hospitals and medical services and allows to count individuals rather than just encounters. A limitation of our study, however, is that the information provided by NPR has not been validated.

Another drawback of our study is that the legislation regarding registration of vaccination in SYSVAK has changed over time, which probably affected the completeness of the data. Before October 2009 only vaccines administered in the childhood immunisation program were mandatory to register in SYSVAK. From January 2011, all administered vaccines should be included, after consent from the patient. The need for consent was removed in January 2020 and electronic vaccine registration was mandated from January 2021 [14]. Thus, it is likely that VC in the splenectomised patients was higher than reported in the period 2008–2010, and that it might become even higher after 2020. Of the 3,155 patients, 76.2% were diagnosed after 2010. Comparing the vaccination rate of the patients included before and after January 2011, we found that the recorded VC was about half for PPV23 and the meningococcal and Hib vaccines before January 2011, while the most significant difference was seen for PCV (4.9% before

Table 4
Cases of invasive infections caused by *N. meningitidis, H. influenzae* and *S. pneumoniae* among splenectomised patients in Norway, 2008–2020.

Patient	Pathogen	Vaccinated against the pathogen	Serogroup - serotype	Vaccine preventable
1	*N. meningitidis*	No	Y	Yes
2	*H. influenzae*	No	Unknown	–
3	*S. pneumoniae*	Yes	Unknown	–
			Unknown	–
			15A	No
4	*S. pneumoniae*	No	35F	No
			35F	No
5	*S. pneumoniae*	Yes	Unknown	–
			23A	No
6	*S. pneumoniae*	No	23A	No
7	*S. pneumoniae*	No	15C	No
8	*S. pneumoniae*	Yes	Unknown	–
9	*S. pneumoniae*	No	35B	No
10	*S. pneumoniae*	No	23B	No
11	*S. pneumoniae*	No	15A	No
12	*S. pneumoniae*	No	19A	Yes
13	*S. pneumoniae*	No	7F	Yes
14	*S. pneumoniae*	No	6C	No
15	*S. pneumoniae*	No	19A	Yes
16	*S. pneumoniae*	No	23F	Yes
17	*S. pneumoniae*	No	24F	No
18	*S. pneumoniae*	No	6A	Yes
19	*S. pneumoniae*	No	16F	No
20	*S. pneumoniae*	No	15B	Yes
21	*S. pneumoniae*	No	7F	Yes
22	*S. pneumoniae*	No	23A	No
23	*S. pneumoniae*	No	Unknown	–
24	*S. pneumoniae*	No	Unknown	–
25	*S. pneumoniae*	No	Unknown	–

January 2011 and 36.5% after; $p < 0.001$). Meningococcal ACWY conjugate vaccines were not generally available in Norway until 2010, but a polysaccharide ACWY was. We could not differentiate between the two vaccines in our study because both were registered in SYSVAK with the same code. Serogroup B meningococcal vaccines on the other hand were not available before 2014. However, 75.0% of the 11 to 20 years old had received two doses or more of serogroup B vaccines (Table 3).

The extent of VC varies greatly between countries, but even when considering the likely underreporting in SYSVAK before 2011, VCs in our study were significantly lower than those reported elsewhere. In a retrospective study conducted in the UK of 100 adult patients who underwent splenectomy and were followed for 5 years, the coverage rate of meningococcal serogroup C, pneumococcal, and Hib immunisations was as high as 91.5%. [5]. Another study from the UK based on clinical records of 293 asplenic patients revealed vaccine coverage against pneumococci, meningococci and Hib to be 91%, 80% and 79%, respectively [15]. High vaccination rates were also documented in a study from Holland involving a small number of patients (91% vaccinated against pneumococci, 58% against meningococci and 83% against Hib) [16]. In a Swedish study of 79 patients who underwent splenectomy between 2000 and 2012, the respective vaccination rates against pneumococcal, meningococcal and Hib infections were 81%, 23%, and 52%, respectively [3]. However, much lower rates were found in Italy in a study of medical records from 166 persons who had total splenectomy in 2012–2013 (13%, 8%, and 6% for pneumococcal, meningococcal and Hib vaccines, respectively) [17]. Pneumococcal, meningococcal and Hib VC rates were similarly low in Poland; 20.0%, 3.5%, and 9.4%, respectively, in a questionnaire study of 85 patients [18]. VC between these studies and ours, however, cannot be directly compared because of difference in study design, health care settings and patient populations. A study that is more similar to ours was performed in Japan on 475 patients between 2 and 64 years of age who underwent splenectomy between 2005 and 2019. The authors reported a VC of PPV23 of 30% using data from health insurance claims databases comprising of employees of different companies [19]. We have used the whole population which have undergone splenectomy for calculation of VC and found a VC of 42% for PPV23. The highest rate of immunisation of splenectomised patients in Norway was seen for pneumococci, followed by the Hib and meningococci as in the literature [17,18,20–22]. Pneumococcal vaccines probably have the highest uptake rates because they have been available and recommended for the longest period, and there is more awareness around pneumococcal disease as it affects more splenectomised patients than any other invasive disease. Due to Norway's extremely low Hib disease incidence and inclusion of the vaccine in the childhood immunisation programme, the Hib vaccine has not been strongly advised for splenectomised patients.

It is difficult to determine the risk of OPSI in patients with asplenia from published literature due to variations in patient demographics and OPSI classifications used. In a review of the literature based on the period 1966–1996, the overall rate of invasive infection was estimated to 3% [23]. However, the term "post-splenectomy infection" has been interpreted variously in different reports, including any hospitalization with an infectious diagnosis. According to a study using patient self-reporting of infections requiring hospitalization for intravenous antibiotics, 26% of patients who had surgical splenectomies required re-admission for specific infectious illnesses [24]. Only twenty-five patients were found to have invasive infections in our investigation, 23 of whom had *S. pneumoniae*. Two of these patients who had pneumococcal infections had undergone full pneumococcal vaccinations in accordance with NIPH recommendations. However, these patients were infected by pneumococcal serotypes (15A and 23A) that could not be prevented by vaccination. More than half of these infections occurred within 24 months post splenectomy, showing that it is crucial to immunize splenectomised individuals soon after surgery.

In Norway, medical personnel at hospitals and community clinics are responsible for offering vaccinations to splenectomised patients. Low VC may be caused by a number of factors, including

lack of awareness of vaccine recommendations and the potential benefits of vaccination among patients and healthcare professionals, a lack of an official vaccination program, vaccine hesitancy, and logistical or financial obstacles. In general, Norway has a high vaccination acceptance rate, as seen by the high adoption of the COVID-19 vaccine program and the childhood vaccination program [10,11]. Vaccination costs for splenectomised patients have been reimbursed by the Norwegian Health Economics Administration since 2011 for pneumococcal and meningococcal vaccines and from 2017 for Hib vaccine. However, until recently meningococcal vaccines were only reimbursed for people under the age of 25. Lack of knowledge of recommendations among patients and healthcare professionals may be a significant factor in the low VC during the study period as there have been numerous updates to the vaccination guidelines for splenectomised patients, new vaccines have been introduced, and SYSVAK registration legislation has changed. All these factors may have contributed to challenging the understanding of the current guidelines by patients and healthcare professionals. Additionally, a lack of knowledge about follow-up vaccination dates among patients and general practitioners (GPs) may contribute to poor VC. VC among asplenic patients could be improved by several measures. Patient education on the risk of complications and preventive measures post splenectomy has been shown to improve VC [25], as well as an active outreach and recall system in outpatient clinics [26]. Healthcare personnel have in other studies called for guidelines clearly stating the division of responsibilities for the follow-up of the patients [27]. Making a GP appointment for the patient before release from the hospital following a splenectomy might also be a significant strategy that can enhance VC. A reminder system could be put in place to keep track of when booster doses are due, in the same way that the national vaccination program follows up the administration of vaccines to the paediatric population.

5. Conclusions

This study showed that splenectomised patients in Norway had less than optimal VC and there is a need for immediate action to ensure that patients receive the immunisations recommended by the NIPH. The management of this patient group can be enhanced by a multidisciplinary strategy that incorporates knowledge of and adherence to national standards, proper patient counselling and automated reminder systems to both patients and healthcare professionals.

This study can be used as a benchmark for further studies of VC in this risk group following the removal of the requirement for consent from the adult patient group and further development of the electronic vaccine registration from January 2021.

6. Funding

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7. Compliance with ethical standards

The Research Project (Project # 265648) obtained ethical approval from the Norwegian Regional Committees for Medical and Health Research Ethics (REK) on 25/06/2021.

Data availability

Data will be made available on request.

Declaration of Competing Interest

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

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