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Interventions delivered in secondary or tertiary medical care settings to improve routine vaccination uptake in children and young people: a scoping review

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ABSTRACT

Objective To identify and analyse the interventions delivered opportunistically in secondary or tertiary medical settings, focused on improving routine vaccination uptake in children and young people.

Design Scoping review.

Search strategy We searched CINAHL, Web of Science, Medline, Embase and Cochrane Database of Systematic Reviews for studies in English published between 1989 and 2021 detailing interventions delivered in secondary or tertiary care that aimed to improve childhood vaccination coverage. Title, abstract and full-text screening were performed by two independent reviewers.

Results After deduplication, the search returned 3456 titles. Following screening and discussion between reviewers, 53 studies were included in the review. Most papers were single-centre studies from high-income countries and varied considerably in terms of their study design, population, target vaccination, clinical setting and intervention delivered. To present and analyse the study findings, and to depict the complexity of vaccination interventions in hospital settings, findings were presented and described as a sequential pathway to opportunistic vaccination in secondary and tertiary care comprising the following stages: (1) identify patients eligible for vaccination; (2) take consent and offer immunisations; (3) order/prescribe vaccine; (4) dispense vaccine; (5) administer vaccine; (6) communicate with primary care; and (7) ongoing benefits of vaccination.

Conclusions Most published studies report improved vaccination coverage associated with opportunistic vaccination interventions in secondary and tertiary care. Children attending hospital appear to have lower baseline vaccination coverage and are likely to benefit from vaccination interventions in these settings. Checking immunisation status is challenging, however, and electronic immunisation registers are required to enable this to be done quickly and accurately in hospital settings. Further research is required in this area, particularly multicentre studies and cost-effectiveness analysis of interventions.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Our analysis and data synthesis have provided the first comprehensive overview of opportunistic interventions to improve uptake of routine vaccinations in secondary and tertiary medical settings.
⇒ We searched a large range of databases over an extensive time period and included studies from all around the world.
⇒ All data screening and extraction were performed by two independent reviewers.
⇒ We did not search the grey literature and may have inadvertently excluded interventions that are used in practice, or that failed to show benefit.
⇒ Only studies published in English were included.

INTRODUCTION

Vaccination has made an enormous contribution to global health. Every year, immunisations save millions of lives and are one of the most successful and cost-effective public health interventions.[1] Despite this, the UK, the USA and other countries with successful immunisation programmes experience outbreaks of vaccine-preventable diseases because of suboptimal vaccine coverage.[2] Health inequalities exist in vaccination, with certain population groups more likely to experience poor coverage.[3] The reasons for these inequalities are complex and influenced by a range of factors including:[3]

- Vaccine hesitancy, due to:
  - Concerns about vaccine safety and efficacy.[4]
  - Misunderstanding around disease severity due to low incidence.[5]
  - Parental/carer resentment of perceived pressure to risk their child's safety for population benefit.[6]
  - Mistrust of healthcare professionals (HCPs), governments and vaccine research.[7 8]
  - Reliance on unofficial information sources.[7 8]
  - Religious vaccination opposition (eg, Orthodox Jewish populations).[9]

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  - Non-religious 'anti-vaxx' sentiment.[10 11]
- Limited access to vaccines, due to:
  - Location/timing of vaccinations.[12]
  - Poor access to HCPs such as health visitors and midwives due to reduced provision.[13]
  - Underserved populations (eg, looked-after children, travellers, refugees/asylum seekers) who experience difficulty accessing healthcare.[14 15]

Despite the success of COVID-19 vaccination programmes, evidence suggests that disruption caused by the pandemic has led to a global reduction in routine vaccination.[16] For example, coverage of the first dose of human papillomavirus virus vaccine in UK females aged 12–13 years fell to 59.2% in 2019/2020, versus 88.0% in 2018/19% and 86.9% in 2017/18.[17] UK childhood vaccinations are normally delivered in primary care settings; however, COVID-19 vaccination has demonstrated the suitability of alternative settings. Children and young people (CYP) can spend significant waiting time in secondary or tertiary care settings, which could be used to provide public health interventions. Indeed, the National Institute for Health and Care Excellence (NICE) recommends that the immunisation status of children be checked at every opportunity, including visits to the emergency department (ED), outpatient clinics and inpatient admissions, with vaccination either offered on the premises or referral to an appropriate vaccination service.[18] NICE has also highlighted groups at risk of underimmunisation, including those with chronic illness or frequent hospitalisations, with secondary/tertiary care representing a key opportunity to vaccinate such children alongside the primary reason for their attendance.[18]

Maintaining vaccination uptake at levels required to prevent community disease spread may necessitate innovative approaches to vaccine delivery. This scoping review seeks to explore interventions delivered in secondary or tertiary medical care settings to improve routine vaccination uptake in CYP.

METHODS

As presented in the published protocol,[19] this scoping review followed the Joanna Briggs Institute (JBI) methodology manual for scoping reviews.[20]

Objective

The scoping review question was:

> What are the interventions delivered in secondary or tertiary medical care settings focused on improving routine vaccination uptake in children and young people?

We aimed to identify and analyse interventions to obtain a broad understanding of how they are delivered in hospital settings and their impact on routine vaccination uptake.

Throughout the review, the terms 'vaccination' and 'immunisation' are used interchangeably. Secondary care generally refers to treatment provided in hospitals, while tertiary care is for patients needing complex hospital treatment.[21]

Eligibility criteria

The review considered studies that described interventions delivered in secondary or tertiary care to improve routine vaccination uptake among CYP published between 1 January 1989 and 11 October 2021. All countries were included. Interventions were considered opportunistic if they were not the primary reason for attending the healthcare setting.

Exclusion criteria

As detailed in the protocol, we excluded studies not published in English.[19]

Search strategy and study selection

On 12 February 2020, we searched CINAHL, Web of Science, Medline and Cochrane Database of Systematic Reviews for articles published between 1 January 1989 and 12 February 2020, using search terms outlined in the protocol.[19] The search was repeated and extended to include EMBASE on 11 October 2021. Duplicates were removed electronically, after which titles and abstracts were screened by two researchers independently before full paper retrieval. At each stage, disagreements were discussed, and consensus reached. Full papers were assessed against the inclusion criteria prior to data extraction and further discussion determined the final study sample. Conference abstracts were excluded due to insufficient information on the included interventions.

Data extraction

A data extraction form was developed using JBI guidelines to collect the information necessary for data synthesis (see online supplemental appendix 1). Two reviewers independently performed data extraction for all studies, with all authors involved at this stage.

Data synthesis

Following data extraction, studies were tabulated by setting and publication date with intervention information presented alongside outcome data. Summary data were also extracted and tabulated based on key characteristics of the studies and interventions. Due to the varied nature of studies and interventions, no meta-analysis was performed.

Deviations from the protocol

Although the protocol stated that we would include children aged under 16 years, we also included studies with an older upper age range (up to 21 years) due to inability to extract data for younger children from these studies.

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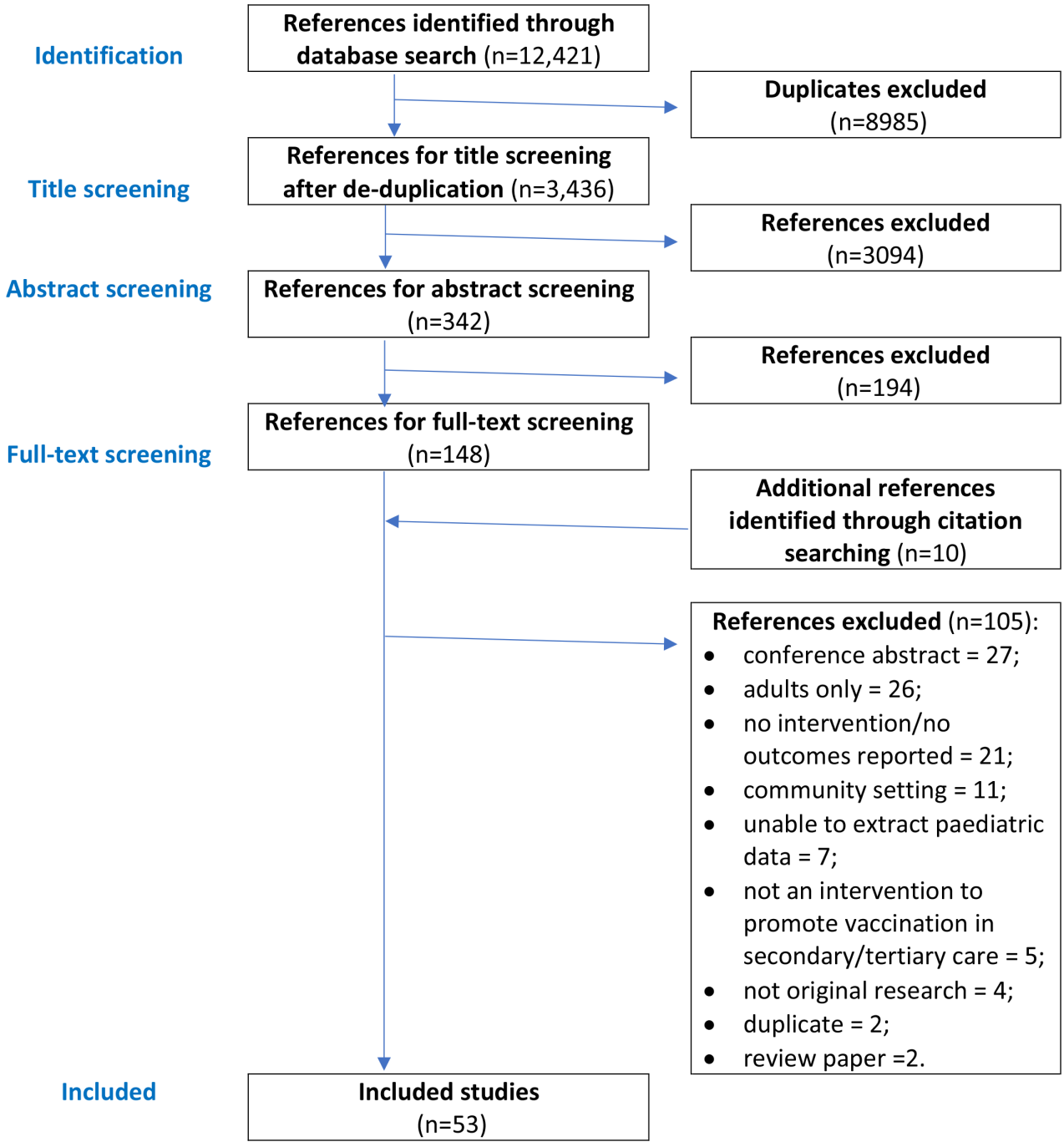

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

Patients and public involvement

No patients or public were involved.

RESULTS

In total, 12 421 titles were returned from the search strategy, after which 8985 duplicates were removed, leaving 3436 for title screening. After this, 342 records remained for abstract screening. Next, 148 full papers were retrieved and underwent full text review. Finally, data were extracted from 53 texts (figure 1). All stages were carried out by two independent researchers.

Study characteristics

The included studies were extremely variable in terms of their population, target vaccination, clinical setting and intervention. Table 1 summarises the general characteristics of the included studies and associated interventions and online supplemental appendix 2 lists all included studies grouped by clinical setting and in chronological order.

General characteristics of studies

The studies were from 14 countries, predominantly the USA, Australia and other high-income countries. The

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Table 1 General characteristics of the included studies and their associated interventions

Characteristic (reference numbers of the included papers)	Frequency, n (%)
Clinical setting*	
Paediatric inpatient wards.[23–25 48 49 54 58 69]	16 (30.2)
Antenatal/neonatal setting[50 56 59 64–68 70 71 84 85]	14 (26.4)
Emergency department (ED)[36–41 51 57 60]	9 (17.0)
Paediatric inpatient wards and outpatient clinics[42 43 52 53 61]	8 (15.1)
Paediatric outpatient clinics[44–47 62 63]	6 (11.3)
Type of hospital	
Tertiary care paediatric hospital[24 33–37 40 43 45 46 49 51–55 57 58 60–62 69]	23 (43.4)
Number of sites	
Single centre[23–30 32–35 37 38 40–44 46–51 53–57 60–64 67–71 85]	41 (77.4)
Multicentre[45 52 58 59 66 84 86 87]	8 (15.1)
Two centres[31 36 39 65]	4 (7.5)
Target immunisation(s)	
All due/overdue vaccinations[23–30 32 33 35 38–42 44 48 49 69]	20 (37.7)
Influenza[31 34 43 45–47 51–55 57 58 60–63]	17 (32.1)
All upcoming vaccinations (for neonates/infants)[64 68 70 71 85]	5 (9.4)
Hepatitis B[65–67 84]	5 (9.4)
BCG[50 56]	2 (3.8)
Measles, mumps and rubella[36 37]	2 (3.8)
'Voluntary' vaccination schedule†[86 87]	2 (3.8)
Country	
USA[24 30 31 34 36 37 39 40 43 46 47 51 53–55 57–63 66 67 69 84]	26 (49.1)
Australia[28 32 33 35 38 41 49 52 65 8528 32 33 35 38 41 49 52 65 85]	10 (18.9)
UK[23 25 27 56]	4 (7.5)
New Zealand[29 42]	2 (3.8)
Japan[86 87]	2 (3.8)
Canada[45 71]	2 (3.8)
South Africa[64]	1 (1.9)
Ireland[50]	1 (1.9)
Bangladesh[48]	1 (1.9)
Nepal[68]	1 (1.9)
India[44]	1 (1.9)
Italy[70]	1 (1.9)
Switzerland[26]	1 (1.9)
Intervention population	
Age group‡	
Includes older children (up to 15–21 years old depending on study)[26 27 30 34 35 38 43 45–49 51–53 55 57 58 61–63]	22 (41.5)
Preschool and younger school-age children only[23–25 28 29 31–34 36 37 39–41 44 60]	16 (30.2)
Neonates/under 1s only (±pregnant women)[50 56 59 64–71 84–87]	15 (28.3)
Family members of child also offered vaccination[45 48 51 52]	4 (7.5)
Risk category for vaccine preventable disease(s) of interest	
All children (low risk and high risk)[23–42 44 46–51 54 56–58 60 62 71 84–87]	42 (79.2)
High risk due to underlying health problem(s)/maternal risk factors[43 45 52 53 55 59 61 63 64 69 70]	11 (20.8)
Study design	
Quality improvement project[34 43 53 54 57 58 61 67 69 84]	10 (18.9)
Clinical audit/service evaluation[28 29 32 41 42 50 56 64 65]	9 (17.0)
Cross-sectional study including description of intervention[23 33 36–38 45 48 60]	8 (15.1)
Intervention study[24–26 35 40 44 52]	7 (13.2)
Randomised controlled trial[47 51 68 71 86 87]	6 (11.3)
Cohort study[39 46 59 66 70]	5 (9.4)
Retrospective case note review[27 31 55 62 63]	5 (9.4)
Pilot study[30 33 85]	3 (5.7)
Aspects of intervention§	
Offer of pre-discharge vaccination at the secondary/tertiary care setting[23–25 27 29–62 64 65 67 69–71 84]	45 (85.9)
Patient/family education[26 34 40 43 48 49 51–55 58 61 63 67 68 70 85–8726 34 40 43 48 49 51–55 58 61 63 67 68 70 85–87]	20 (37.7)
Extra staff/funding involved in delivering the intervention[24 32–34 36 39 40 42 48–53 68 87]	18 (34.0)
Training, education and/or promotional materials for staff[24 32–34 37 38 41 44 52–54 61 63 67 69 84 8524 32–34 37 38 41 44 52–54 61 63 67 69 84 85]	17 (32.1)
Multidisciplinary approach to leadership and delivery incorporating medical, nursing and pharmacy colleagues[24 33 34 45 54 55 57–59 61 67 84]	12 (22.6)
Automatic vaccine ordering/in-built order sets[43 46 54 57 58 61 65 66]	8 (15.1)
Ongoing feedback to staff regarding the success/uptake of the intervention[34 37 53 54 61 84]	6 (11.3)
Collaboration with other external organisations[24 37 45 52]	4 (7.5)
Method of screening vaccination eligibility¶	
Patient/parental recall[23 29–32 36–41 44 48 51 56 57]	16 (30.2)

Continued

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Table 1 Continued

Characteristic (reference numbers of the included papers)	Frequency, n (%)
Handheld written record/immunisation card[24–26 29 30 36 37 39 40 44 48 56]	12 (22.6)
A local electronic clinical system that alerts staff of eligible patients[33 34 43 52 57–63]	11 (20.8)
Checking against national/regional immunisation registry[23 28 32 33 35 41 42 54]	9 (17.0)
Checking with primary care provider[24 30]	2 (3.8)
Not required as universal vaccination offer[50 59 64 68 70 71 84 8550 59 64–68 70 71 84–87]	13 (24.5)

*1 study included both ED and inpatient wards.
†In Japan, the vaccination schedule is subdivided into 'routine' and 'voluntary' vaccinations.[88]
‡Total does not equal 53 (100%) due to studies also including family members.
§Total does not equal 53 (100%) due to interventions containing multiple components.
¶Total does not equal 53 (100%) as some studies used more than one method.

most common settings were inpatient wards, followed by antenatal/neonatal settings, EDs and outpatient clinics. A range of age groups were examined in individual studies, with the most frequent being children of all ages, followed by younger age groups and four studies also including family members. Several vaccinations were studied, most commonly all due/overdue immunisations and influenza. Various study designs were used, encompassing quality improvement (QI) projects, clinical audits/service evaluations, cross-sectional studies, intervention studies, randomised controlled trials, cohort studies and pilot studies.

Characteristics of the interventions

Interventions varied substantially according to their content and delivery. Most involved predischarge vaccination and a third involved extra resources. Other common features were patient/family education, staff training/education, a multidisciplinary approach and the use of automatic vaccine ordering. The most common approach to checking immunisation status was parental/carer recall.

Note on settings

There were some considerations specific to setting, particularly neonatal settings. Here, several studies explored hepatitis B and BCG vaccination administered post birth. Although opportunistic in that it took place in hospital without appointment, this was often the recommended care setting for the vaccination. For example, national policy in the UK is for babies born to mothers with hepatitis B to receive vaccination within 24 hours of birth, usually in hospital.[22]

The pathway to successful opportunistic vaccination in secondary and tertiary care

The heterogeneity of the included studies illustrates that opportunistic vaccination represents a complex pathway and involves several steps to be successful, all with potential for patient drop-out. We have attempted to summarise this pathway below and provide a narrative summary of the approaches and interventions used at each stage:

1. Identify patients eligible for vaccination.
2. Take consent and offer vaccination.
3. Order/prescribe vaccine.
4. Dispense vaccine.
5. Administer vaccine.
6. Communicate with primary care.
7. Ongoing benefits of vaccination.

It should be noted, however, that not all interventions will encompass all steps; for example, educational interventions delivered in hospital, but where vaccination occurs in the community.

Identify patients eligible for vaccination

Baseline vaccination coverage

Several studies had assessed baseline vaccination coverage to determine the pool of eligible patients.[23–46] For all due/overdue vaccinations, baseline coverage ranged from 44%[24 40] to 89%,[35] with little difference by setting and lower coverage in older studies. For influenza, baseline coverage was lower, ranging from 25%[47] to 50.5%.[31]

Determining immunisation status

For vaccination to be successful, eligible patients must be accurately identified. This requires individual data, such as age, presence of underlying disease, immunisation status and clinical condition.

Checking immunisation status (henceforth referred to as 'screening') was most straightforward in neonatal studies where all infants were generally eligible. However, the complexity increased with age and cumulative number of required vaccinations. The target vaccination and setting were also important. As a single yearly vaccination, screening influenza vaccination status was more straightforward. In outpatient studies, patients had an ongoing relationship with the teams, reducing the complexity of screening, while inpatient stays afforded greater time to screen. Contrastingly, in ED there was limited time and rapid patient turnover.

In terms of personnel, screening was most successful in studies with extra staff and/or funding, including dedicated research staff.[24 32–34 39 42 48–53] Elsewhere, there was no clear consensus regarding who was best placed for this task, although two studies had successfully used pharmacy staff.[54 55]

A range of methods were used to screen immunisation status.

Patient/parental recall

Used in 30.2% of studies, this was the most common approach.[23 29–32 36–41 44 48 51 56 57] Although straightforward,

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it was inaccurate for studies of all due/overdue immunisations and was more appropriate for influenza. Szilagyi *et al* found that 20% of children reported as underimmunised in ED were actually up to date, while a quarter of those reported as up to date were underimmunised.[39] When compared with immunisation registers, Ressler *et al* and Riley *et al* found that immunisation status based on recall was incorrect for 14.5% and 32.1% of patients, respectively.[23 28]

Electronic clinical alert system

These were used by 20.8% of all studies and involved influenza and hepatitis B vaccination.[33 34 43 52 57–63] Systems were designed to generate automatic vaccination alerts, based on age and clinical risk factors. Alerts were often delivered alongside other digital initiatives, such as automatic ordering, or within wider QI initiatives. However, Pollack *et al* found automated screening to be a predictor of inpatient influenza vaccination uptake.[46]

Handheld immunisation documentation

This was used in 22.6% of studies, usually alongside other methods.[24 26 29 30 36 37 39 40 44 48 56] The approach was unreliable, with Cunningham *et al* and Lindegren *et al* finding that 56% and 24%–26% of patients respectively had no documentation with them in ED.[36 40]

Phone calls to primary care

Two studies had screened immunisation status by telephoning primary care.[24 30] This was inefficient, with Bell *et al* reporting an average of 1.5 calls to obtain a vaccination record and 4–5 hours spent daily calling primary care.[24]

Checking against a national or regional immunisation registry

This was the gold standard and most accurate approach. Two UK studies had combined checking handheld documentation with telephoning the local health authority to check registry data.[23 25] Several Australian studies had used the Australian Immunisation Register, a national register that records all vaccines administered and which staff can access remotely.[28 32 33 35 41] A New Zealand study had used a similar approach.[42]

Confirming clinical condition is compatible with vaccination

At this stage of the pathway, the patient's clinical condition and any clinical contraindications must also be considered. Studies reported varying proportions of children too ill to be vaccinated, ranging from 0% to 20.5% and with no obvious relationship to setting.[23 31 34 36 38 42 46 51 53 64] Leading reasons to defer vaccination were fever, diarrhoea, upcoming/recent surgery, vaccine allergies or oncology patients undergoing treatments.

Take consent and offer immunisations

Although clinical contraindications were important, vaccines not being offered and parent/carer refusal were greater contributors to non-uptake. Non-offer ranged from 11% to 77%, with the upper and lower range both in studies examining all due/overdue vaccines.[25 37 42 44] No studies had evaluated why vaccines were not offered.

Many studies had explored parent/carer refusal of vaccination.[25 31 37 38 42 46 48 51 56 60 65] This varied according to target vaccination and was low for neonatal vaccines, with Bakshi and Sharief reporting that 1% of parents refused neonatal BCG vaccination and Connors *et al* reporting that parental refusal was rarely or never a reason for not vaccinating against hepatitis B at birth.[56 65] In contrast, refusal was higher for other vaccines in high-income countries. Here, for measles, mumps and rubella (MMR) or all due/overdue vaccines, parental refusal ranged from 9.4% to 37.5% where vaccination status was known, with Cunningham *et al* also reporting 87.5% refusal where status was unknown.[25 37 38 40 42] For influenza, refusal ranged from 25.6% to 72% and was greater when offered in the ED.[31 46 51 60] Across all vaccinations, four studies had evaluated underlying reasons, with common responses encompassing preference for vaccination in primary care, belief that the child was too unwell, concerns about the safety and efficacy of vaccination and belief that it was not needed for healthy children.[31 40 46 47]

Order/prescribe vaccine

Several studies of influenza and neonatal hepatitis B vaccination used automatic ordering/built-in order sets.[43 46 54 57 58 61 65 66] Massey *et al* found that admission orders were associated with increased neonatal hepatitis B vaccination and Connors *et al* found that uptake of hepatitis B vaccination in a hospital where it was on a standing order was 93%–96% versus 71%–77% where it was not.[66]

Dispense vaccine

Pharmacy involvement was frequently identified as essential to ensuring that vaccines were consistently available and dispensed quickly, with pharmacy staff involved in the leadership and delivery of several interventions.[41 54 57 61 67] Gattis *et al* described a pharmacy-led intervention for influenza vaccination of solid organ transplant recipients whereby pharmacists were responsible for screening patients, assessing appropriateness, recommending vaccination to providers, educating patients/family and verifying and dispensing vaccines.[55] Vaccination uptake rates increased from 36% pre intervention to 72% post intervention ($p<0.001$), with influenza diagnoses also falling.[55]

Administer vaccine

Next, vaccinations must be administered, with the potential for further drop-out. This was evidenced by Orenstein *et al* and Rao et al.[54] who had evaluated how vaccine orders translated into administration, with only 40.3% and 61.2% of those with orders receiving vaccination, respectively.[54 58]

For each study, online supplemental appendix 2 summarises baseline coverage and subsequent outcomes, including administration and uptake of vaccination. Although uptake varied by study, virtually all demonstrated an improvement in coverage post intervention. It

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Table 2 Ranges of administration of vaccination among eligible patients across the included studies by setting and target vaccination

Setting	Target vaccination (reference numbers of the included papers)		
	Measles, mumps and rubella	Influenza	All due/overdue
Emergency department	35%–41%[36 37]	8.8%–57%[51 57 60]	24.0%–75.0%[38–41]
Inpatients	–	31.0%–69.1%[31 34 54 58]	3.4%–80.0%[23–30 32 33 35]
Outpatients	–	8.0%–90.3%[45–47 62 63]	53.6%–84.6%[42 44 48 49]*
Inpatients and outpatients	–	49.7%–87.4%[43 52 53 55 61]	
	BCG	Hepatitis B	All neonatal/infant immunisations
Neonatal/antenatal	80%–85%[50 56]	72.52%†–100%[59 65–67 84]	91.3%–96.0%[64 68–71 85–87]

*Combined as there was only one study conducted exclusively in outpatients.
†Mercier *et al* reported 30% uptake of neonatal hepatitis B vaccination but this coincided with the phasing out of this policy and the introduction of hexavalent vaccination containing hepatitis B at 2, 4 and 6 months and is not included in the range.

is difficult to compare administration rates due to variable study conditions and outcome measures; however, table 2 summarises ranges by setting and vaccination.

Looking first at influenza, higher uptake was generally seen in inpatients and outpatients than EDs, and in studies of children with underlying medical conditions.[43 52 53 55 61] The highest uptake (90.32%) was reported by Lo and Sobota in an outpatient study of children with sickle cell disease.[63] Similarly, Pappano *et al* and Rao *et al* found that underlying medical conditions were associated with increased vaccination.[51 54]

For all due/overdue vaccinations, there was higher uptake in studies with dedicated immunisation staff.[33 35 36 39 40 48 49] Outside of these, intervention uptake was higher in older studies, with studies published pre-2000 reporting uptake of 65%–82.4% and those post-2000 reporting uptake of 3.4%–64%.

Uptake of neonatal vaccines was generally high. However, it was often unclear to what extent this was a consequence of the intervention, with little difference in outcomes pre intervention/post intervention or when compared with control. For example, Bolam *et al* reported 94% uptake of infant immunisations in the control group versus 96% in the intervention group.[68] In studies of preterm and high-risk infants, however, interventions to increase uptake of routine vaccinations at chronological age through parental and staff education showed a marked improvement.[64 69 70]

Communicate with primary care

After vaccine administration, primary or community care providers must be informed. This was a further benefit of a remotely accessible vaccination registry, as used in Australia and New Zealand, with primary care updated of any vaccinations administered via this route.[42]

Communication with primary or community care was also important to arrange vaccination of children not vaccinated in hospital. In some studies, patients were referred to primary care if they were not vaccinated in hospital. In others, such as Muehleisen *et al*, there was no in-hospital offer of vaccination, with the intervention consisting of education and a prompt to arrange vaccination and primary care informed as such.[26] Here, 27% of patients in the intervention group had received vaccination 1 month post discharge, compared with 8% of the control (p<0.001).[26]

Ongoing benefits of vaccination

Although not strictly part of the vaccination pathway, some studies had evaluated whether interventions had lasting impacts on coverage and vaccination behaviour.

Four studies had explored whether gains in coverage were sustained beyond the intervention's initial timeframe (table 3). In the two examining all due/overdue vaccinations, initially increased uptake associated with the intervention was not sustained.[26 39] Similarly, Kushner *et al* found that coverage of hepatitis B vaccination fell with time.[59] However, in these studies it was unclear whether, in the absence of the intervention, coverage would have been even lower. In their study of all infant immunisations, Lemaitre *et al* found that uptake was consistently higher in the intervention group at all timepoints.[71]

DISCUSSION

As far as we are aware, this is the first attempt to review the literature relating to opportunistic vaccination across secondary and tertiary care settings and we have provided a comprehensive overview of interventions used to improve vaccination in these settings. Despite established childhood immunisation programmes internationally, there were relatively few published papers available. Similarly, although NICE recommends opportunistic vaccination in the UK, there were only four papers published between 1991 and 2007.[15 23 25 56] Our review has demonstrated that opportunistic vaccination in hospital settings is complex, requiring several steps to be successfully navigated for interventions to be effective.

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Table 3 Summary of included studies detailing sustained coverage outcomes beyond the initial timeframe of the intervention

Study (target vaccination)	Baseline coverage	Postintervention coverage	Sustained coverage: timepoint 1	Sustained coverage: timepoint 2
Muehleisen *et al* (all due/overdue vaccinations)[26]	► Intervention group=54% ► Control group=49%	Patients with ≥1 catch-up immunisation within 1 month: ► Intervention group=27%. ► Control group=8% (p<0.001)	Patients with ≥1 catch-up immunisation within 9 months: ► Intervention group=45% ► Control group=35% (p>0.2)*	–
Szilagyi *et al* (all due/overdue vaccinations)[39]	64%	Fully immunised for age at 1 day: ► Manhattan ED=75% ► Bronx ED=71%	Fully immunised for age at 6 months: ► Manhattan ED=66% ► Bronx ED=54%	–
Lemaitre *et al* (all upcoming neonatal vaccinations)[71]	Not applicable (neonates)	Complete vaccine status at 3 months: ► Experimental group=91.3% ► Control group=88.1%	Complete vaccine status at 13 months: ► Experimental group=66.2% ► Control group=59.5%	Complete vaccine status at 24 months: ► Experimental group=79.4% ► Control group=74.3%
Kushner *et al* (neonatal hepatitis B vaccination)[59]	Not applicable (neonates)	Birth dose of hepatitis B vaccination=100%	Dose 2 (1–2 months)=81%	Dose 3 (6–18 months)=74%

*Exact p value not provided.
ED, emergency department.

Vaccination coverage among CYP attending secondary and tertiary care appears to be below that of the general paediatric population.[72–75] This was evaluated by some of the included studies, with, for example, Shingler *et al* reporting coverage of 70.6% in their study population versus a regional average of 85% and Tarca *et al* reporting coverage of 75% in their first study cohort versus a state and national average above 91%.[35 42] This is important in the context of suboptimal uptake of many UK vaccinations, with only 85.3% having received the preschool booster and 86.6% the second MMR dose by age 5 in 2020/2021.[76] With ongoing outbreaks of vaccine-preventable diseases, such as measles and pertussis, opportunistic vaccination in hospital-based settings may represent one route through which to vaccinate an underimmunised patient subgroup.[77 78]

An important finding was that, although the effect sizes were variable, virtually all interventions led to an improvement in coverage post intervention. This suggests that interventions were able to reach and vaccinate patients not vaccinated via traditional methods. Previous literature has shown that a key barrier to childhood vaccination is access, including time constraints, distance, location, long waiting times, childcare challenges for siblings and impermanent residence for groups such as homeless or looked-after children.[79] Clearly, opportunistic vaccination overcomes these barriers and provides an opportunity to inform parent/carer knowledge about vaccination. Both Gilbert and Wrigley, and Conway reported that a leading reason for underimmunisation in the community were minor illnesses at the intended time of vaccination, as identified previously in the vaccination literature.[25 29 79] Thus, hospital settings may present a useful opportunity to discuss true medical contraindications to vaccination and to vaccinate children in a setting where they can be monitored and their safety assured.

This review found consistent evidence that the effectiveness of opportunistic vaccination depends on the ability to quickly and accurately assess vaccination status, particularly for all due/overdue vaccines. National UK policy is for patients to be offered vaccines if their current vaccination status is unknown.[80] However, Cunningham *et al* found that parents were reluctant to do so, with uptake of catch-up vaccinations in ED only 15% among patients with uncertain status compared with 71% with documented underimmunisation (p<0.0001).[40] The review demonstrated that parental recall and handheld records were unfeasible screening options due to unreliability and unavailability, while confirming with primary care was time-consuming. Consequently, a remotely accessible electronic system is required to achieve this successfully, as demonstrated by studies using the Australian Immunisation Register.[28 32 33 35 41] In the absence of this, inpatient admissions may be appropriate for catch-up of routine immunisations due to the prolonged time in hospital. Influenza vaccination may be possible in more time-pressured ED and outpatient settings due to the reduced screening required alongside the opportunity to use digital initiatives that reduce the burden on staff, such as electronic alerts and automatic vaccine ordering. This is especially relevant given that influenza vaccine uptake in the UK is lower than other childhood vaccines, with 56.7% uptake among 2 and 3 year olds in 2020/2021.[81] In the UK,

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the National Health Service is transitioning to a digital handheld child health record (the 'eRedbook') from 2023, which may improve the long-term feasibility of opportunistic catch-up vaccination, although alternative short-term and medium-term interventions are likely to be required.[82 83]

Several studies described interventions that used additional staff and/or funding, which were generally more successful than those that did not. Even with digital interventions, delivering vaccination alongside routine care may be challenging without additional resources. In the study by Burgess *et al*, ED staff were reluctant to take on responsibility for vaccination and felt that they lacked sufficient time.[38] Likewise, Cunningham *et al* described how, in the absence of the dedicated immunisation nurse, combining tasks with the existing duties of ED staff made immunisation a low priority, while Buenger and Webber reported that ED staff prioritised other tasks over influenza vaccination.[40 57] In the inpatient setting, Walton *et al* found that over half of staff expressed concerns or considered inpatient vaccination inappropriate.[27] Therefore, it is important that new interventions are adequately resourced, with implementation facilitated by staff education and QI methodologies to ensure that they become embedded within care.[24 34 42 54] Additional factors limiting intervention success were high levels of parental refusal and non-offer of vaccination by staff. There has been extensive research into refusal of community-based vaccination; however, future work should seek to understand the specific barriers underlying parental refusal and non-offer of opportunistic vaccination in hospital settings.

Limitations

The included papers provided variable information about the interventions, often with limited detail rendering evaluation difficult. In addition, most interventions had used several components making it difficult to draw out the impact of individual aspects. Most were single centre studies that reported on local initiatives and it is challenging to determine their wider generalisability. Although studies demonstrated improved vaccination coverage, none had evaluated cost-effectiveness and few had evaluated the medium-term/long-term impact of interventions. Nevertheless, NICE suggests that any intervention that improves vaccination coverage is usually cost-effective, particularly if it benefits underserved groups.[18] We did not search the grey literature and may have missed interventions used in practice via this route—this also increases the risk of publication bias. Additionally, we only included studies published in English, potentially biasing findings towards those from English-speaking countries. As with all scoping reviews, we did not formally evaluate evidence quality and, due to the studies' varied nature, only limited synthesis of results was possible.

CONCLUSIONS

This scoping review has explored and summarised the published literature relating to interventions delivered in secondary and tertiary settings focused on improving routine vaccination uptake in CYP, with most studies demonstrating improved vaccination coverage post-intervention. Furthermore, children attending hospital appear to have lower baseline coverage than the general paediatric population and are likely to benefit from interventions in these settings. For interventions to be successful, however, there is a need for electronic immunisation registers to enable vaccination status to be quickly and accurately checked, with the UK's transition to the eRedbook a potential long-term route to facilitate this. Although existing research suggests that opportunistic vaccination interventions in hospital settings may be beneficial, further research is needed in this area, particularly multicentre studies and cost-effectiveness analysis.

Contributors SB was involved in the design of the study, title, abstract and full-text screening, and data extraction. In addition, SB performed the analysis and data synthesis, wrote the first draft of the manuscript and undertook subsequent revisions to the manuscript. RE contributed to the coconception of the study, design of the study, the literature search and project management. RE was also being involved in title, abstract and full-text screening, data extraction, and the write-up of the manuscript at all stages. RI contributed to the coconception of the study, design of the study, title, abstract and full-text screening, and data extraction, along with supporting oversight of the project. RE and RI contributed equally to this paper and wish to be listed as joint last authors. KN, NG, LT, SS and MO contributed to data extraction. All authors were involved in critically revising the manuscript and approved the final version for submission. RE, RI and SB act as guarantors for this study.

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Appendix 1 – Data extraction instrument

Scoping review details	
Scoping review title:	A scoping review of interventions delivered in secondary or tertiary medical care settings to improve routine vaccination uptake in children and young people.
Review objective/s:	To identify and synthesize the available quantitative evidence to produce a map of public health interventions to improve vaccination uptake in children and young people that are delivered in secondary and tertiary healthcare settings.
Review question/s:	What are the interventions delivered in secondary or tertiary medical care settings focused on improving routine vaccination uptake in children and young people?
Inclusion/exclusion criteria	
Population	Children and young people (aged less than 16 years)
Context	Interventions to improve routine vaccination uptake delivered in secondary or tertiary medical care settings.
Types of study	Quantitative
Study details and characteristics	
Study citation details (e.g. author/s, date, title, journal, volume, issue, pages)	
Study design	
Country	
Setting (e.g. secondary care, ED, inpatient ward)	
Participants (details e.g. age/sex, number)	
Population sub-group	
Vaccination target (e.g. MMR, influenza, all)	
Details/results extracted from study (in relation to the concept of the scoping review)	
Intervention	
Outcome	

Cost effectiveness/effectiveness	
Acceptability to stakeholders	
Any differential effects	

Appendix 2: Key characteristics and outcomes of included studies

Interventions delivered in the emergency department (ED)					
Author, year/country (reference number)	**Type of study - target vaccination (n)**	**Intervention summary (study population – age/characteristics)**	**Vaccine coverage amongst study population at baseline**	**Key results and outcomes reported**	
Lindegren et al., 1993/USA(54).	Cross sectional study, two centres – measles, mumps and rubella (MMR) (n=763).	Opportunistic MMR vaccination in two EDs during a measles outbreak including dedicated vaccination nurses (6-60 months).	**History of MMR vaccination:** • Hospital A = 72%. • Hospital B = 60%.	**Opportunistic MMR vaccination amongst those eligible:** 41%.	
Schlenker et al., 1995/USA(55).	Cross sectional study, single centre – MMR (n=541).	Opportunistic MMR vaccination in an ED during a measles outbreak (0-4 years).	**History of MMR vaccination:** • Vaccinated = 83%. • Uncertain = 10%. • Unvaccinated = 7%.	**Opportunistic MMR vaccination amongst unvaccinated children:** • Vaccinated in ED = 25%. • Refused vaccination = 37.5%. • Not offered vaccination = 37.5%. **Factors associated with vaccination:** Children presenting to ED with physical injury compared to children with respiratory illness.	
Burgess et al., 1996/Australia (56).	Cross sectional study, single centre* - all due/overdue vaccinations (n=5,162).	Screening vaccination status and offering opportunistic vaccination in an ED, GP practices and Early Childhood Centers (0-15 years).	**Fully immunised for age:** 71%.	**Catch-up vaccinations delivered:** 33% (of under-immunised children across ED, general practices and Early Childhood Centres). **Parental refusal of opportunistic vaccination:** 10%.	
Szilagyi et al., 1997/USA(57).	Prospective cohort study, two centres - all due/overdue (n=484).	Screening immunisation status and offering opportunistic vaccination in two EDs by project nurses (0-6 years).	**Fully immunised for age:** 64% (both hospitals).	**Timescale**	**Children fully immunised for age (%)**
					Manhattan ED / **Bronx ED**
				1 day	75% / 71%
				6 months	66% / 54%
Cunningham et al., 1999/USA(58).	Intervention study, single centre - all due/overdue (n=9,321).	Dedicated immunisation nurses in ED screening vaccination status and offering missing immunisations (0-72 months).	**Documented vaccination status:** 44%. **Fully immunised for age:** 44%.	**Uptake of catch-up vaccinations in ED:** • Amongst patients with documentation of under-immunisation = 71%. • Amongst patients with no documentation of vaccination status = 15% (p<0.0001, documentation of under-immunisation versus no documentation).	

Author, year/country (reference number)	**Type of study - target vaccination (n)**	**Intervention summary (study population – age/characteristics)**	**Vaccine coverage amongst study population at baseline**	**Key results and outcomes reported**
Skull et al., 1999/Australia (59) (N.B. also includes inpatients).	Clinical audit, single centre – all due/overdue (n=866).	Education sessions, prompts within patient records and offer of vaccination pre-discharge for inpatients and ED patients (<7 years).	**Vaccination coverage at baseline:** • Pre-intervention = 74%. • Post-intervention = 60%.	**Opportunistic vaccination amongst eligible patients:** • Pre-intervention = 0. • Post-intervention = 24% (p=0.002 compared to pre-intervention).
Pappano et al., 2004/USA(60).	Randomised controlled trial (RCT), single centre – influenza (n=337).	Families randomised to opportunistic influenza vaccination in ED (whole family offered vaccination) or education only (0-19 years).	Information not provided.	**Families with 1 or more family members vaccinated:** • Vaccine offered (intervention) = 75%; Education only (control) = 55% (relative risk = 1.36, 95% confidence interval (CI) = 1.11-1.67). **Vaccine uptake for paediatric patients:** • Vaccine offered (intervention) = 57%. • Education only (control) = 36%. **Factors associated with vaccination:** • Age <6 months (odds ratio (OR) = 0.05, 95%CI = 0.01-0.27). • Influenza vaccination prior to enrolment (OR = 11.58, 95%CI = 5.54-24.20). • Intervention study arm (OR = 7.47, 95%CI = 4.57-12.22). • History of heart disease (OR = 5.74, 95% CI = 1.34-24.54). • Unspecified chronic illness (OR = 3.05, 95%CI = 1.27-3.51).
Buenger and Webber, 2020/USA(61).	Quality improvement (QI) project, single centre – influenza (n=32,231).	Series of electronic triggers, alerts and orders in patient records to increase opportunistic influenza vaccination in ED (≥6 months).	Information not provided.	**Vaccination uptake – proportion of eligible visits:** • Pre-intervention (2013/14) = 0.3%. • Post intervention (2014/15) = 8.8%.
Strelitz et al., 2021/USA(62).	Cross-sectional study, single centre – influenza (n=152).	Screening vaccination eligibility and offer of influenza vaccine in ED (≥6 months – 7 years).	Information not provided.	**Uptake of influenza vaccination in ED:** 37%. **Demographics associated with vaccine refusal:** • High school education or less (OR = 0.4, 95% CI = 0.2-0.9). • Ethnicity – Hispanic/Latino (OR = 0.2, 95% CI = 0.1-0.6).

Interventions delivered in paediatric inpatients				
Author, year/country (reference number)	**Type of study (target vaccination)**	**Intervention summary**	**Vaccine coverage amongst study population pre-admission**	**Key results and outcomes reported**
Riley et al., 1991/UK(22).	Cross-sectional study, single centre – all due/overdue (n=296).	Offer of overdue vaccinations for inpatients (5 months – 6 years).	**Vaccination coverage at baseline:** 81.1%.	**Vaccination uptake at discharge amongst all eligible cases:** 75%.
Bell et al., 1997/USA(24).	Intervention study, single centre - all due/overdue vaccinations (n=2,006).	Programme to vaccinate under-immunised pre-school inpatients before discharge (0-2 years).	**Fully vaccinated:** 44%. **Due for next vaccination:** 33.4%. **Overdue:** 17.7%.	**Opportunistic catch-up vaccinations amongst those eligible:** • 66% received at least 1 immunisation. • 55.8% received multiple immunisations. • 50.6% were brought up to date. **Fully immunised for age at discharge:** (70% versus 44% at baseline, p<0.001).
Conway, 1999/UK(25) .	Intervention study, single centre – all due/overdue (n=1,000).	Discussion of the importance of vaccination with families of inpatients and offer of immunisation pre-discharge (3-66 months).	**Vaccination coverage at baseline:** 80%.	**23% of eligible children were offered immunisation as an inpatient:** • 65% accepted. • 35% of parents/carers refused.
Muehleisen et al., 2007/ Switzerland(26).	Intervention study, single centre – all due/overdue (n=430).	Under-immunised inpatients encouraged to arrange missing vaccines and primary care physicians informed (61 days – 17 years).	**Vaccination coverage at baseline:** • Intervention group = 54%. • Control group = 49%.	**Catch-up immunisations at 1 month:** • Intervention group = 27%. • Control group = 8% (p<0.001). **Immunisation coverage at 9 months:** • Intervention group = 45%. • Control group = 35%.
Walton et al., 2007/UK(27).	Retrospective case note review, single centre – all due/overdue (n=207).	Offer of inpatient vaccination pre-discharge (≥3 months).	**Vaccination coverage at admission:** 69%.	**Proportion of those eligible vaccinated pre-discharge:** 3%.
Ressler et al., 2008/Australia (28).	Clinical audit, single centre – all due/overdue (n=539).	Vaccination catch-up plans given by nursing staff (2-24 months).	**Fully immunised for age:** 86%.	**Vaccinated within 30 days of admission:** • Those with a catch-up plan = 57%. • Those without a catch-up plan = 15%.
Gilbert and Wrigley, 2009/New Zealand(29).	Clinical audit, single centre – all due/overdue (n=369).	Documentation of immunisation status for inpatients, catch-up immunisations as an inpatients or referral to GP (3-23 months).	**Fully immunised for age:** 60%.	**Of children behind with immunisation:** • 36% had a reason recorded. • 3.4% given catch-up immunisations on the ward. • 4.2% referred to primary care for vaccinations. • No action documented in remainder.

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary	Vaccine coverage amongst study population pre-admission	Key results and outcomes reported
Pollack et al., 2014/USA(72).	Retrospective cohort study, single centre – influenza (n=42,716).	Screening for eligibility, automatic ordering and administration of inpatient influenza vaccination (≥6 months).	**Already vaccinated at time of screening:** 49.2%.	**Vaccination uptake (all subjects):** • Pre-intervention = 2.1%. • Post-intervention = 8% (p<0.001 compared with pre-intervention). **Factors associated with vaccination uptake:** • Automated screening (OR = 6.77, 95% CI = 6.14-7.47). • Female gender (OR = 0.88, 95% CI = 0.8-0.96). • Race – Native Hawaiian/Pacific Islander (OR = 1.85, 95% CI = 1.15-3.30). • Ethnicity – Non-Hispanic/Latino (OR = 0.77, 95% CI = 0.66-0.89). • Unit of admission (surgical unit = baseline) – Medical unit (OR 1.79, 95% CI = 1.6-1.99), Rehabilitation unit (OR 4.27, 95% CI = 3.19-5.72), Psychiatric unit (OR 1.63, 95% CI = 1.39-2.02). • High-risk status (OR 0.77, 95% CI = 0.67-0.87). • Age – 5-12years (OR 1.26, 95% CI = 1.1-1.44), >12 years (OR 1.44, 95% CI = 1.26-1.65).
Pahud et al., 2015/USA(30).	Pilot study, single centre – all due/overdue (n=356).	Screening immunisation status and offering required vaccinations pre-discharge (<18 years).	**Fully immunised for age:** 73%.	**Age appropriately immunised at 1 month:** 80% (compared to 73% at baseline, p<0.001). **Percentage of under-immunised children appropriately caught-up at 1 month:** 25%. **Factors associated with under-immunisation:** Children aged ≥11 years (p<0.001).
Cameron et al., 2016/USA(31).	Retrospective case note review, two centres – influenza (n=786).	Influenza assessment form followed by offer of vaccination for inpatients (6 months – 8 years).	**Influenza vaccination coverage at baseline:** 50.5%.	**Influenza vaccination uptake amongst those eligible:** 50.1%. **Factors associated with vaccine acceptance:** • Private health insurance (OR = 0.6, 95% CI = 0.37-0.97). • Child up-to-date with routine immunisations (OR = 2.39, 95% CI = 1.05-5.41).
Jose et al., 2016/Australia (32).	Clinical audit, single centre – all due/overdue (n=188).	Immunisation status screening using national registry and employment of dedicated nurse to immunise eligible inpatients (2 months – 6 years).	**Vaccine coverage of inpatients:** 81.4%.	**Vaccination outcomes amongst inpatients eligible for vaccinations:** 8% received immunisations in hospital.
Elia et al., 2017/Australia (33).	Pilot study, single centre – all due/overdue vaccinations (n=3,374).	In-house dedicated immunisation service including screening inpatients and offering vaccinations pre-discharge (6 weeks – 7 years).	**Vaccination coverage of inpatients:** 75%.	**Vaccination outcomes amongst the 25% of inpatients eligible for vaccinations:** 42% brought up-to-date.

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary	Vaccine coverage amongst study population pre-admission	Key results and outcomes reported
Rao et al., 2018/USA(34).	QI project, single centre - influenza (n=2,552).	Multi-component QI project targeting influenza vaccination of inpatients (<32 months).	**Already vaccinated at admission:** 35%.	**Percentage of patients with an influenza order during hospitalisation:** • Intervention group 1 (provider reminders) = 52%. • Intervention group 2 (family education) = 30%. • Comparison group = 25% (p<0.0001, versus intervention group 1). **Percentage of patients immunised against influenza (includes those vaccinated pre-admission):** • Intervention group 1 = 61%. • Intervention group 2 = 52%. • Comparison group = 53% (p=0.0017, versus intervention group 1).
Rao et al., 2020/USA(36).	QI project, single centre – influenza (n=8,573).	Multi-component QI project targeting influenza vaccination of inpatients (≥6 months).	Information not provided.	**Percentage of patients with an influenza order during hospitalisation:** • Pre-intervention period = 28.8%. • Intervention period = 50.2% (p<0.001). **Percentage of patients vaccinated at discharge:** • Pre-intervention period = 61.8%. • Intervention period = 69.1% (p<0.001). **Predictors of vaccine ordering:** • Intervention (odds ratio (OR) = 2.27, 95% confidence interval (CI) = 2.01-2.56). • Government insurance. • Underlying medical condition. • Increased length of stay. • Admission from ED. • Being asked about vaccination status on admission. **Predictors of being vaccinated at discharge:** • Intervention (OR = 1.39, 95% CI = 1.27-1.53). • Younger age. • Underlying medical condition. • Increased length of stay. • Admission to a sub-specialty team. • Admission from ED. • Being asked about vaccination status on admission.

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary	Vaccine coverage amongst study population pre-admission	Key results and outcomes reported
Orenstein et al., 2021/USA(38).	QI project, multi-centre – influenza (n=17,740).	Multi-component QI project to increase uptake of influenza vaccine amongst inpatients (≥6 months).	Information not provided.	**Proportion of eligible hospitalisations with at least 1 dose of vaccine pre-discharge:** • Intervention group = 31%. • Concurrent control group = 19% (p<0.001 compared with intervention). • Historical control group = 14% (p<0.001 compared with intervention). **Proportion of eligible hospitalisations with an influenza vaccine order placed pre-discharge:** • Intervention group = 77%. • Concurrent control group = 27% (p<0.001 compared with intervention). • Historical control group = 15% (p<0.001 compared with intervention).
Tarca et al., 2021/Australia (39).	Intervention study, single centre – all due/overdue (n=563).	Dedicated immunisation service for inpatients including screening for eligibility and vaccination pre-discharge (<18 years).	**Vaccination coverage at admission:** • Pre-intervention = 75%. • Post-intervention = 89%.	**Vaccination coverage at 3 months amongst those not fully immunised for age:** • Pre-intervention = 28%. • Post-intervention = 64%.

Interventions delivered in paediatric outpatients							
Author, year/country (reference number)	**Type of study (target vaccination)**	**Intervention summary**	**Vaccine coverage amongst study population pre-admission**	**Key results and outcomes reported**			
Deivanayagam et al., 1995/India(69).	Intervention study, single centre – all due/overdue (n=634).	Educational intervention for clinicians, immunisation screening, documentation change and offer of opportunistic vaccination for outpatients (<2 years).	**Children eligible for immunisations:** • Medical outpatients = 26.5%. • Newborn outpatients = 31.8%. • Immunisation clinic = 8.7%.	**Setting**	**Baseline - %**	**Post-intervention 1 - %**	**Post-intervention 2 - %**
				Missed opportunities			
				Medical outpatients.	35.5	24.5	18.4 (p=0.001 compared with baseline)
				Newborn outpatients.	23.1	12.2	8.0
				Immunisation clinic.	9.7	0	0 (p=0.001 compared with baseline)
				Advised immunisation by clinician			
				Medical outpatients.	-	2.0	18.4
				Newborn outpatients.	-	24.5	30.4
				Immunisation clinic.	-	8.7	16.0
				Improvement in children immunised (compared to baseline)			
				Medical outpatients.	-	-	16.4
				Newborn outpatients.	-	-	5.9
				Immunisation clinic.	-	-	7.3
Patwardhan et al., 2011/USA(70).	Retrospective case note review, single centre – influenza (n=4,778).	Electronic health record reminder for influenza vaccination of outpatients (1-21 years).	Information not provided.	**Vaccination uptake:** • 2007/08 (pre-intervention) = 15.4%. • 2008/09 (pre-intervention) = 17.6%. • 2009/2010 (post-intervention) = 34.9%.			
Dubé et al., 2014/ Canada(71).	Cross-sectional study, multi-centre – influenza (n=2,478).	Offer of influenza vaccination for children with chronic illness (and their household contacts at one site) in outpatient clinics (2-17 years).	**Pre-intervention coverage (based on previous years):** 35%.	**Uptake of influenza vaccination in clinic:** 60%.			

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary	Vaccine coverage amongst study population pre-admission	Key results and outcomes reported
Hutchison et al., 2018/USA(73).	RCT, single centre – influenza (n=235).	Randomised to treatment as usual or offer of influenza vaccine in outpatient clinic (≥6 months – 18 years).	**Vaccination coverage at baseline:** • Intervention group = 27%. • Control group = 25%.	**Intervention group outcomes:** • Vaccination uptake during clinic visit = 39%. • Total vaccination coverage at end of clinic visit = 67% (p<0.001 compared with control group).
Lo and Sobota, 2019/USA(74).	Retrospective case note review, single centre – influenza (n=124).	Screening immunisation status, arranging influenza vaccination and educational materials for families and clinicians (6 months – 18 years with sickle cell disease).	Information not provided.	**Influenza vaccine uptake:** 90.32%. **Tested positive for influenza:** 4.84%. **Influenza-related hospitalisations:** 0.

Interventions delivered in paediatric inpatients and outpatients

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary	Vaccine coverage amongst study population pre-admission	Key results and outcomes reported
Islam et al., 1992/ Bangladesh(23).	Cross sectional study, single centre – all due/overdue (n=212,206).	Preventive health service comprising health education and immunisation (all inpatient and outpatient children and their mothers).	Information not provided.	**Catch-up immunisation amongst children with incomplete immunisation:** **Timescale** / **Immunised** / **Contraindicated** / **Refused** 1989 / 84.6% / 2.84% / 0.98% 1990 / 82.4% / 1.44% / 1.10% 1991 / 74.6% / 5.83% / 1.9%
Britto et al., 2007/USA(63).	QI project, single centre – influenza (n=18,866).	Multi-component QI project to vaccinate inpatients and outpatients (0-16 years with underlying medical conditions).	Information not provided.	**Total of patients vaccinated against influenza across all settings:** 49.7% (ranging from 38.9% in new hospital clinics – 82.1% in cystic fibrosis clinics). **Vaccine refusal:** 0-12%.
Wood and Cashman, 2011/ Australia(64).	Intervention study, multi-centre – influenza (n=3,458).	6-month period with nurse immunisers to vaccinate inpatients and outpatients. Parents and siblings of children with medical conditions also offered vaccinations (≥6 months).	Information not provided.	**Number of vaccines administered to children and their families:** 3,458 vaccines. **Percentage of vaccines administered to children with chronic medical conditions:** 36%.

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary	Vaccine coverage amongst study population pre-admission	Key results and outcomes reported
Shingler et al., 2012/New Zealand(76).	Clinical audit, single centre – all due/overdue (n=5,583).	Opportunistic vaccination of inpatients and outpatients (≤32 months).	**Fully immunised for age:** 70.6%.	**Outcomes for under-immunised children:** • Opportunistically vaccinated = 53.6%. • Medical indication not to immunise = 20.5%. • Missed opportunities = 11%. • Preferred to defer immunisation to be given in primary care = 5.4%. • Chose not to immunise = 9.4%.
Freedman et al., 2015/USA(66).	QI project, single centre – influenza (n=1,128).	Multi-component QI project to increase uptake of influenza vaccine (oncology inpatients and outpatients ≥6 months).	**Vaccination uptake pre-intervention:** • Complete vaccination = 44.4%. • Partial vaccination = 10.4%. • Unvaccinated = 45.2%.	**Vaccination uptake post-intervention (p value – comparison to pre-intervention):** • Complete vaccination = 64.5% (p<0.001). • Partial vaccination = 13.0% (p=0.19). • Unvaccinated = 22.5% (p<0.001).
Olshefski et al., 2018/USA(67).	QI project, single centre - influenza (n=872).	Multi-component QI project to vaccinate inpatients and outpatients (paediatric oncology patients undergoing active treatment).	Information not provided.	**Timescale:** / **Percentage of eligible patients vaccinated against influenza:** / **Percentage of eligible patients not offered influenza vaccination:** 2012/13 – 74.9% – 19.8% 2013/14 – 88.5% – 2.1% 2014/15 – 89.3% – 0.5% 2015/16 – 88.5% – 3.8% 2016/17 – 87.4% – 2.5%
Gattis et al., 2019/USA(68).	Retrospective case note review, single centre – Influenza (n=800).	Screening for eligibility and opportunistic vaccination of inpatients and outpatients (solid organ transplant recipients <18 years).	Information not provided.	**Opportunistic inpatient flu vaccination:** • Pre-intervention (2011) = 19%. • Post-intervention (2016) = 72%, p<0.001. **Time from beginning of flu season to 50% influenza vaccination:** • Preintervention (2011) = 163 days. • Post-intervention (2016) = 94 days, p<0.001. **Influenza diagnosis rates:** Declined amongst vaccinated compared to unvaccinated in each season, significant difference in 2014. **Influenza hospitalisation:** No significant differences.

Author, year/country (reference number)	**Type of study (target vaccination)**	**Intervention summary**	**Vaccine coverage amongst study population pre-admission**	**Key results and outcomes reported**
Elia et al., 2021/Australia (37).	Cross-sectional study, single centre – all due/overdue (not provided).	In-house immunisation service including offer of immunisations to inpatients and drop-in clinic for outpatients and visitors (all children).	Information not provided.	**Increase in the proportion of inpatients opportunistically immunised since employment of the immunisation nurse practitioner:** 15%.
Interventions delivered in neonatal/antenatal settings				
Author, year/country (reference number)	**Type of study (target vaccination)**	**Intervention summary (study population)**	**Key results and outcomes reported**	

Bakshi and Sharief, 1993/UK(40).	Clinical audit/service evaluation, single centre – BCG (n=201).	BCG vaccination of neonates at high-risk of TB on post-natal ward (neonates).	**Uptake of BCG vaccination in the neonatal period:** 85%.
			• Vaccinated in hospital before discharge = 84%.
			• Vaccinated in the community = 1.5%.
			• Unimmunised = 14.4%.
			  o Never offered vaccination = 5.5%.
			  o Parents refused vaccine = 1%.
			• Moved out of area and lost to follow-up = 8%.	

Bolam et al., 1998/Nepal(41).	RCT, single centre – all infant vaccinations (n=540).	Mothers randomised to educational intervention at birth and 3 months, birth only or control (neonates).	**Immunisation coverage at 6 months:** • Group A (health education on post-natal wards and at 3 months post-natal) = 95%. • Group B (health education on post-natal wards only) = 96%. • Group C (health education at 3 months only) = 93%. • Group D (no intervention) = 94%.	
Connors et al., 1998/ Australia(42).	Service evaluation, two centres – hepatitis B (n=4,165).	Birth dose of hepatitis B vaccination on post-natal ward (neonates).	**Hepatitis B vaccine uptake pre-discharge**	
			Timescale / 1993 / 1994	**Hospital A** / 96% / 93%	**Hospital B** / 71% / 77%
			Factors associated with vaccination: • Use of standing orders for hepatitis B vaccination. • Routinely recommending hepatitis B vaccination for both low and high-risk neonates.	
Mercier et al., 2007/USA(43).	QI project, multi-centre – hepatitis B (n=719).	A multi-aspect QI intervention covering various aspects of post-natal health care including neonatal hepatitis B vaccination on post-natal wards (neonates).	**Hepatitis B vaccination uptake:** • Pre-intervention = 45%. • Post-intervention = 30%.	

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary (study population)	Key results and outcomes reported
Braima et al., 2010/ Ireland(44).	Clinical audit/service evaluation, single centre – BCG (n=4,368).	Policy to universally offer BCG vaccination on post-natal ward (neonates).	**Uptake of BCG vaccination in hospital:** 80%.
Saitoh et al., 2013/Japan(45).	RCT, multi-centre – voluntary vaccinations (n=119).	Mothers randomised to educational intervention delivered antenatally, postnatally or control (neonates).	**Uptake of voluntary vaccines at 3 months:** • Intervention group 1 (pre-natal education) = 29.4%. • Intervention group 2 (education on post-natal wards) = 38.9%. • Control group (care as usual) = 8.3%.
Massey et al., 2015/USA(47).	Retrospective cohort study, multi-centre – hepatitis B (n=20,442).	Implementation of 2015 national policy to deliver dose of hepatitis B vaccination pre-discharge from maternity unit (neonates).	**Hepatitis B vaccination uptake in post-natal unit:** 80.2% **Factors associated with hepatitis B vaccination:** All births – • Hospital birth. • Medical attendant at birth. Hospital births only – • Illicit drug use. • Maternal age <35 years. • Weekday birth. • Use of admission orders.
Saitoh et al., 2017/Japan(46).	RCT, multi-centre - voluntary vaccinations (n=188).	Mothers randomised to educational intervention (delivered antenatally, on the post-natal ward and at 1 month) or control (mothers/neonates).	**Uptake of voluntary vaccinations at 2, 3 and 4 months as measured at 6 months:** • Intervention group (prenatal education and education on post-natal wards) = 43.0%. • Control group = 45.5%.
Schniepp et al., 2019/USA(35).	QI project, single centre – all due/overdue (n=54).	Education for nurses and clinicians in cardiac critical care to increase uptake of due/overdue immunisations for neonates with congenital heart defects (≤1 year).	**Immunisations given/parent refusal documented pre-discharge:** • Baseline = 57.1%. • Post-intervention = 87.5%.

Author, year/country (reference number)	**Type of study (target vaccination)**	**Intervention summary (study population)**	**Key results and outcomes reported**		
Lemaitre et al., 2019/ Canada(48).	RCT, single centre – all upcoming vaccinations (n=2,572).	Randomised to treatment as usual or motivational interviewing on post-natal wards (parents/neonates).	**Timeframe (months)** 3 5 7 13 19 24	**Vaccine coverage – experimental group** 91.3% 83.2% 75.9% 66.2% 56.7% 79.4%	**Vaccine coverage – control group** 88.1% 78.3% 68.6% 59.5% 46.1% 74.3%
			Predictors of vaccination status at 24 months: • Intervention group (OR = 1.05, 95% CI = 1.02-1.07). • Complete vaccination status at 3 months (OR = 6.81, 95% CI = 5.58-8.30).		
Tooke and Louw, 2019/South Africa(49).	Clinical audit, single centre – routine infant vaccinations (n=60).	Vaccination of neonatal unit inpatients at chronological age pre-discharge (pre-term neonates).	**Vaccination uptake amongst infants admitted at 6 weeks:** • 95% received their 6 weeks vaccines. • 5% were not vaccinated due to being too unwell.		
Bradshaw et al., 2020/USA(50).	QI project, single centre – hepatitis B (n=21,108).	Multi-component QI project to increase uptake of birth dose of hepatitis B vaccine (neonates).	**Newborn hepatitis B vaccination pre-discharge:** • Pre-intervention = 52.4%. • Post-intervention = 72.5%.		
Kaufman et al., 2020/ Australia(51).	Pilot study, single centre – all infant vaccinations (n=62).	Educational intervention for midwives and pregnant women targeting antenatal and newborn immunisations (pregnant women/neonates).	**Uptake of birth hepatitis B vaccine:** 91%. **Uptake of two-month childhood immunisations:** 96%.		
Kushner et al., 2021/USA(52).	Cohort study, multi-centre – hepatitis B (n=372).	Electronic alerts and a joint liver/obstetric clinic to increase uptake of hepatitis B vaccine and immunoglobulin (neonates of mothers with hepatitis B).	**Uptake of hepatitis B vaccine (uptake at correct time interval):** • Dose 1 = 100% (91%). • Dose 2 = 81% (78%). • Dose 3 = 74% (49%).		

Author, year/country (reference number)	Type of study (target vaccination)	Intervention summary (study population)	Key results and outcomes reported
Di Mauro et al., 2021/Italy(53).	Prospective cohort study, single centre – all infant vaccinations (n=170).	Parental education, health promotion materials and vaccinations offered at chronological age for inpatients (pre-term neonates).	**Vaccination coverage at 24 months in pre-term study cohort (comparison with historical cohort of pre-term infants):** • DTaP-IPV-HBV-Hib dose 2 – 98.2% vs. 91.2% (p=0.009). • DTaP-IPV-HBV-Hib dose 3 – 96.4% vs. 87.3% (p=0.005). • MMR – 94.6% vs. 76.4% (p<0.001). • Varicella – 94.6% vs. 80.9% (p<0.001). • No significant difference for DTaP-IPV-HBV-Hib dose 1, PCV doses 1-3 and Men C. **Vaccination coverage at 24 months in pre-term study cohort (compared with regional paediatric population):** • No significant difference in coverage of any vaccination dose. **Age of vaccine administration in pre-term study cohort compared to recommended age:** Timeliness of vaccination significantly delayed for all vaccination doses.

*Single secondary/tertiary care setting included in study, along with primary care settings