OBJECTIVES To gain insight in the potential of the current pipeline for rabies to decrease the burden of disease by evaluating its relevance to high-risk countries.

METHODS Rabies-related patent documents and clinical trials were retrieved from Espacenet and the WHO ICTRP, respectively. Data were cleaned, modulated and categorised into a pre-defined set of indicators those were used for (statistical) analyses on the number of patent applications, patent quality and type of stakeholders involved for different geographical areas.

RESULTS Analysis of 583 unique patent families applied for in the period 1954–2017 showed a steep growth in the yearly number of patent applications. A significant portion of new patent applications concern Chinese patents with relatively low quality that are filed by a dispersed group of applicants. Excluding these patents, the number of patent applications has been virtually stable over the years. A shift is seen in public stakeholders becoming more prolific as patent applicants. This shift is also reflected in clinical trials; key sponsors of clinical trials include public and private stakeholders originating from high-risk rabies countries. The majority of clinical trials investigate adjustments to existing vaccines that may improve accessibility.

CONCLUSION The results show a discrepancy between the quantity and quality of rabies patent applications that reflects national patent regulations rather than real progress in decreasing the burden of disease. This is in contrast to clinical trials, which focus on incremental innovations that are tested in clinical trials but may nevertheless have a potentially strong impact in high-risk countries.

KEYWORDS rabies, neglected tropical diseases, patents, clinical trials, innovation, quality

Sustainable Development Goals (SDGs): SDG 3 (good health and well-being), SDG 9 (industry, innovation and infrastructure)

Introduction

Rabies is an invariably fatal disease that is transmitted to humans through bites of infected animals. Human rabies can be prevented though pre- and post-exposure prophylaxes, but these approaches are costly and require multiple visits following a strict administration schedule. These product characteristics hamper uptake among travellers [1–3] and moreover among populations living in high-risk settings, resulting in 59 000 deaths and 3.7 million DALYs each year [4]. Despite the clear and widely recognised need for inexpensive and easy-to-use prophylaxes [5], innovation activities are still limited, making rabies one of the most neglected tropical diseases (NTDs).

International attention has resulted in increased research and development activities in NTDs, including rabies. Several studies show increased research activities in terms of scientific publications [6], patent applications [7] and clinical trials [8]. Different technological advances may aid the development of novel products against rabies, such as reverse genetics for the development of improved vaccines, and monoclonal antibodies to replace immunoglobulins [9–13]. In the past, such technological advances indeed led to improved rabies vaccines [9] and lowered the disease burden [14,15].

Unfortunately, however, not all novel medicines and technologies lead to improved health outcomes. Improved health outcomes are only achieved if novel products are
superior to existing products, or have improved accessibility for highly affected populations. This is especially relevant for rabies, given the fact that current rabies prophylaxes are primarily targeted at low-risk, high-income countries for which a relatively large market exist [16], whereas the disease burden is primarily located in high-risk, low-income countries [14]. A highly effective novel vaccine may thus have limited societal impact if it would become accessible to the same target population or to patients in a single country only. Instead, novel products should become widely accessible in low-income, high-risk rabies countries to substantially decrease the burden of disease.

There thus remains a persistent need for improved medical interventions that can address the burden of diseases especially in high-risk countries. Although previous studies have described the innovation landscape in quantitative terms [7,8], there is currently no insight into the relevance of these efforts for meeting societal and medical needs. The current study aims to address this knowledge gap and gain insight in the potential of the current pipeline to decrease the burden of disease by evaluating its relevance to high-risk rabies countries.

**Methods**

A comprehensive overview of the rabies pipeline was obtained by studying patents and clinical trials. Clinical trials and patents are measures of the output of early- and late-stage research, respectively. Virtually all inventions in the pharmaceutical sector are covered by patents as they are the only way of offering solid intellectual property protection of new pharmaceutical compounds [17–20]. However, a significant share of inventions disclosed in patents will not enter clinical testing due to disappointing research results, or due to strategic reasons [21]. Patent data alone could thus lead to an overly optimistic outlook. To mitigate this, this study includes an analysis of patent quality, by building upon multiple indicators to reduce variance [22,23].

Especially in the context of neglected tropical diseases, patent data can also be incomplete since some inventions skip early-stage research and enter clinical trials immediately. This is the case for repurposed drugs that are based on existing compounds, and it is an endorsed approach for drug development in the field of NTDs [24,25]. Clinical trials represent late-stage drug development that all new inventions must pass before market entry, which make clinical trials a reliable indicator of the pipeline on the short-term.

By combining clinical trial data for insight into the short-term, and patent data for insight into the medium to long-term, this study provides a comprehensive overview of the pipeline for medical interventions against rabies disease.

**Patents**

**Data collection and selection.** Patent data were retrieved from Espacenet, a worldwide database containing over 100 million patent documents from over 90 patent-granting authorities. Compared to other databases, Espacenet contains the best features for the search and selection of relevant patents [26]. The search criteria for the dataset consisted of rabies-related Cooperative Patent Classification (CPC) codes, covering the complete Rhabdoviridae family, the Lyssavirus genus and rabies virus species (Appendix S1). Additionally, a search was done for title or abstract containing the terms ‘rhabdovir*’, ‘lyssa*’, ‘rabies’ and ‘rabid’. The search criteria were quality checked by an external expert on biomedical intellectual property from the Netherlands Enterprise Agency (RVO), a department of the Dutch Ministry of Economic Affairs. Data were retrieved on March 31st 2017 and exported to Microsoft Excel.

All patent documents were deduplicated based on patent family (i.e. multiple jurisdictional filings related to a single invention) via priority numbers. For each patent family, the primary patent document (with the oldest application date) was identified for further analysis. Given the broad search terms, the data set contained irrelevant patents that were excluded based on title and abstract screening. Patents were excluded based on the following criteria: not related to rabies (e.g. treatment for another disease); non-medical (e.g. dog muzzles); lack of evidence for anti-rabies activity (e.g. rabies named as a potential future application) and; non-available abstract. Although monopoly rights are only awarded after careful examination of the invention (e.g. granted patents), all relevant patent families were included in the analysis regardless of status, since each patent family represents an interest among applicants to address a certain market. The final dataset thus comprised primary patent documents on inventions with a medical application against rabies for human and/or veterinary use.

**Data modulation and analysis.** To understand the potential impact of inventions the target markets of patented inventions were analysed. Given the high costs related to patenting, there is a direct relation between the location of patent applications and target markets [27]. Patents are generally only applied for in countries where they are expected to bring a substantial economic benefit, either by generating revenues or by preventing competitors to enter the market. To analyse which markets are considered attractive for novel medical interventions against
rabies, countries were categorised based on the risk level for attaining human rabies, as determined by the WHO [28]. Patent documents filed in more than one country were categorised as being applied for the country with the highest rabies risk level. Patent families for which only documents with kind codes belonging to the World Intellectual Property Organization (WIPO) or European Patent Office (EPO) were retrieved, were not included in this specific analysis.

Patent quality. Based on empirical evidence available in literature, a quality index using five indicators was developed for this study. For each indicator, cut-off points were set in order to categorise a patent as either high or low quality and the combined score was translated into a quality label. Patents were categorised according to the number of quality indicators they met: five (quality A), four (quality B), three (quality C), two (quality D), one (quality E) or none (quality F). High-quality A patents were granted in at least one country; were filed in more than one country; were filed in at least one country other than the country of origin of the applicant; did not describe a traditional medicine and; were cited by at least one other patent.

The first indicator of quality was whether a patent was granted or not. Patents were considered to be of higher quality if they were granted in at least one country, since patents are only granted after careful examination by patent examiners on whether the document adheres to a number of patent criteria (e.g. novel, useful, non-obvious). In addition, obtaining patent protection is considered essential for the further development and market introduction of pharmaceutical products [17]. To study the legal status of patents, all published documents related to the same patent family were obtained. Using the kind codes of these documents, patent documents were categorised as granted, applied or other (Appendix S2).

The second and third indicators are measures of the economic value of a patent. Applying a patent is time- and cost-consuming, and is therefore generally done only if the expected economic benefits outweigh the efforts. Efforts and costs increase with the number of countries in which a patent application is filed, also referred to as the size of the family [23,29], and when it is filed outside the patent applicant’s domestic country [30,31]. For this study, patents are considered to be of higher quality if the patent family is larger than 1 and if a patent is applied for in at least one country other than the country of origin of the patent applicant. The necessary information was retrieved by analysing the country codes of all published documents in the patent family and comparing them with the country codes of the applicant(s).

Fourth, patent quality is linked to the potential patentability of inventions abroad. Although patent criteria are internationally agreed upon, harmonisation is not perfect and the terms utility, novelty, and non-obviousness have slightly different meanings in different countries [22]. The difference that is specifically relevant for this study relates to traditional medicines, which are patentable in China, but not in most other countries since they lack the required novelty [32]. These medicines, based on local beliefs, are unlikely to be widely adopted in other areas and also unlikely to contribute to a decrease in burden of disease. Therefore, while patents on traditional medicines are potentially great in number, they are categorised as lower quality patents.

Finally, the quality of patents is strongly correlated to the number of patents citing the patent [23,29,33]. Such forward citations (FCTs) are the most studied quality indicators [23,29,33,34] and have shown to be most informative for patent value in the field of drug development [23]. Patents with a high number of FCTs disclose inventions that are subsequently used for the development of other, new inventions and therefore have a high technological value. Typically, such citations are independently assigned by patent examiners. For this study, we consider patents with at least one FCT to be of higher quality than patents with no FCTs. The number of FCTs were manually retrieved from the Espacenet database. FCTs become publicly available upon publication of the citing patent, which generally takes 18 months from the filing date and thus at least 18 months from the publication date of the initial patent [27]. Therefore, only patents published 18 months before the search date (before October 2015) were included in the quality assessment.

Statistical analyses
Statistical analyses were performed to identify whether associations between the location of patent filings and the type of applicant were statistically significant. The background of patent applicants, and by extension their primary objectives, has an important impact on the entire innovation process, including the target market chosen [35]. For example, while public stakeholders may grant exclusive licences on inventions to ensure further investments and development [36], they generally focus on societal impact over economic return, which a priori makes patent applications and clinical studies by this stakeholder group relatively more promising for high-risk and resource-poor settings. Private stakeholders, on the other hand, often use patents solely for the purpose of blocking competitors from the market [18,22]. Analysis of the stakeholder type thus enhances the interpretation.
of the relevance of the data for the target market. To this purpose, unique patent applicants were identified and patent applicants were categorised into private and public stakeholders as an indication of the extent to which they strive for either maximising economic return (private stakeholders), vs. societal impact through development and commercialisation (public stakeholders).

Considering the smaller need to obtain a return on investment, we hypothesised that public stakeholders are more interested in the development of products for high-risk rabies countries, and thus in seeking patent protection in these countries, than their private counterparts. Data was converted in \( 2 \times 2 \) tables to calculate Odds Ratios and perform Fisher’s exact test. If the \( 2 \times 2 \) table included a zero, 0.5 was added to all cells to calculate the OR [37].

Clinical trials

Data on clinical trials were gathered from the WHO International Clinical Trials Registry Platform (ICTRP), which provides data on active and ongoing trials. The WHO ICTRP database is updated on a weekly basis to merge information from databases from the United States, Europe, Australia, New Zealand, and China. All active and ongoing trials with the search term ‘rabies’ in title or condition were included. The database was accessed on May 12th 2017, all trial information was exported to Excel and deduplicated based on trial ID. Given the database’s broad definition of rabies (‘hydrophobia, lyssa, other and unspecified viral infection, viral infection, rabies’), the retrieved subset included irrelevant trials that did not focus on the indication rabies. These were manually excluded from the dataset. Missing values were corrected or complemented by referring to the original documents and databases.

Clinical trial sponsors were categorised in the same categories as patent applicants and key sponsors were identified based on the number of clinical trials. Subsequent in-depth analysis included a comparison between the clinical trials sponsored and the patents filed by these actors to understand the relevance of their efforts to high-risk countries.

Results

The initial search retrieved 1527 raw patent documents. After patent family collapse (\( n = 1045 \)) and exclusion of non-relevant patent families (\( n = 462 \)), 583 relevant patent documents remained, covering the period from 1954 to March 2017. For the purpose of the different analyses, these documents were re-expanded for national filings (\( n = 2243 \)), the number of applicants (\( n = 733 \)), or the origin of patent applicants (\( n = 590 \)) (Figure 1). The 583 primary patent documents were applied for in 61 (currently existing) countries by 293 unique institutional (public or private) applicants, originating from 26 countries. A total of 143 patent families were filed at the WIPO.

The clinical trial search identified 224 records describing clinical trials that were active and ongoing on May 12th 2017. After deduplication of trial ID (\( n = 6 \)) and exclusion of irrelevant trials (\( n = 133 \)), 84 unique trials were included for further analysis. Most trials investigated rabies vaccines (\( n = 59 \)), followed by immunoglobulins (\( n = 22 \)), adjuvants (\( n = 3 \)) and an injection device (\( n = 1 \)). The final dataset included 17 phase I, 22 phase II, 23 phase III and 27 phase IV studies. The clinical trials were active or ongoing in May 2017 and registered between 2005–2017. The clinical trials were sponsored by 36 unique sponsors, originating from high (15), moderate (15), low (4) and no (2) risk countries.

Rabies risk vs. location of patents

Analysis of the location of rabies patent applications revealed an inverse relationship between the number of patent applications and the rabies risk level in a country. Patent applications were primarily filed by applicants originating from low rabies risk countries and they are also largely filed in low rabies risk countries (Figure 2a-c). The exception is China, which is the only high-risk country with high numbers of rabies-related patent applications. Figure 2d shows (i) that this is a recent trend: both the number and share of patent applications in high-risk countries steeply increased between 2000 and 2017, from 22 (14%) to 316 (54%), and (ii) that this growth can be attributed primarily to Chinese patents.

Patent quality

To interpret the relevance of the patent growth, subsequent analyses were performed on the quality of patents filed before Oct 2015 (\( n = 529 \)). A total of 58 patents (11%) were identified as high-quality A patents, meeting all quality indicators (Table 1). High-quality A and B patents mainly differ from lower quality patents by being filed in more than one country, and by being filed in a country foreign to the patent applicant. Low-quality E patents, on the other hand, include many patents that describe traditional medicines and patents that are not (yet) granted.

Out of 529 patent applications, 272 patent applications were filed in China. A total of 36 (13%) patent documents were filed in another country (including PCT applications) prior to being filed in China. The remaining 236
(87%) patent documents were initially filed in China and only 6% of Chinese patent applications were subsequently also filed in another country. A relatively large proportion of Chinese patent applications concerned traditional medicines (19%) and less than half of all Chinese patent applications were granted (47%). In conclusion, the overall quality of Chinese patents is low compared to other patents (Table 1).

Interest of stakeholder types

Figure 3 reveals a shift in the types of stakeholders involved in rabies-related inventions. Historically, the vast majority of patents was filed by companies, but other stakeholder groups have increasingly contributed to new patent applications since the 2000s. Despite a stable growth in patent applications by private stakeholders, their relative contribution to new applications declined from 59% to 45%. Public stakeholders increasingly contribute to patent applications while joint patents from a collaboration between public and private stakeholders (PPPs) are still scarce (n = 18). In contrast to patents applied for in other territories, a relatively large proportion of Chinese patents were filed by non-institutionalised inventors.

To gain insight in the potential effect of the shift in stakeholder type, subsequent analyses were performed on the location of patent applications per stakeholder type. Considering the skewed Chinese patent data, these patents were excluded from the analysis, leaving a total of 327 patent families. Figure 4 shows large and statistically significant (two-sided Fisher’s exact test, or FET) differences in the interest of stakeholder types. Compared to other stakeholders, private stakeholders file statistically significantly more patents in low-risk countries (OR = 1.7; P ≤ 0.05, FET), but also in high-risk countries (OR = 2.2; P ≤ 0.01, FET). In contrast, public stakeholders demonstrated statistically significantly less interest in high-risk countries (OR = 0.4; P ≤ 0.01, FET) and more interest in moderate-risk countries (OR = 4.3; P ≤ 0.001, FET) compared to other stakeholder groups.

Key stakeholders of patents and clinical trials

In line with the increased interest from public stakeholders, the top 3 key applicants of rabies patents are all

Figure 1 Patent data syntax
public stakeholders (Table 2). Table 2 also shows, however, that the relative market shares of key stakeholders declined considerably over the years, revealing an increasingly fragmented market. The patent landscape used to be dominated by a few companies each holding up to 80% of all patents. Together, the top 3 applicants filed one-third of all patent applications per time period until 1987. With growing numbers of patent applications per time period, the share of key applicants declined and in the most recent time period (2008–2017), key applicants filed maximum of 5% of all patents.

Public stakeholders also play a significant role as sponsors of clinical trials (42%), but there is little overlap between key applicants of patents (Table 2) and the key sponsors of clinical trials (Table 3). Out of 18 key sponsors of clinical trials, 11 did not file a single patent, which is in line with the finding that many clinical trials (50; 60%) focus on the investigation of existing drugs. These studies include post-marketing studies, but also adjustments to the administration dose, regimen and administration route of products. As an example, among the sponsors of such trials is lead clinical trial sponsor Novartis. The clinical trials sponsored by this company focuses on comparing their proprietary, existing rabies vaccines, despite having filed a patent on a novel adjuvant and obtaining another exemplary patent on rabies vaccine from Chiron Behring in 2007 (EP1593392(A1)). Thus, there is no direct link between the number of patent applications filed by a sponsor and the innovativeness of the products tested in clinical trials.

Among the clinical trial sponsors is a striking large number of sponsors from high-risk countries holding no patents. Clinical trials that are sponsored by these stakeholders either investigate existing products (Queen Saovabha Memorial Institute, India and Beijing Center for Disease Control and Prevention, China) or novel products that are patented by applicants from low-risk countries. For example, the patents of the University of Massachusetts appear in the clinical trials that are sponsored by the Serum Institute of India. The only exemption is Zydus Cadila, which filed two patents and sponsored two related clinical trials.

**Conclusions and discussion**

This study shows intensified innovation activities for rabies in recent years that cannot be simply interpreted as an improved product pipeline that will reduce the burden of rabies disease. On the positive note, the increased involvement of public stakeholders as patent applicants and the high share of public stakeholders from high-risk countries as sponsors of clinical trials, provides hope on

| Quality label | All patents | Chinese patents | Granted | Filed | Not traditional medicine | Forward citations ≥ 1 | Family size > 1 | n = 216 | n = 230 |
|---------------|-------------|----------------|---------|-------|--------------------------|----------------------|-----------------|--------|--------|
| F             | 0           | 0              | 0       | 0     | 0                        | 0                    | 0               | 0      | 0      |
| E             | 10          | 1              | 10      | 1     | 1                         | 1                    | 1               | 1      | 1      |
| D             | 91          | 91             | 91      | 91    | 91                        | 91                   | 91              | 91     | 91     |
| C             | 87          | 87             | 87      | 87    | 87                        | 87                   | 87              | 87     | 87     |
| B             | 58          | 58             | 58      | 58    | 58                        | 58                   | 58              | 58     | 58     |
| A             | 110         | 110            | 110     | 110   | 110                       | 110                  | 110             | 110    | 110    |
| Quality indicator | F | A B C D E F | A B C D E F | A B C D E F | A B C D E F | A B C D E F | A B C D E F | A B C D E F | A B C D E F |

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incremental and affordable innovations that will impact high-risk rabies countries.

A steep increase in the number of patent applications can be attributed primarily to high-risk country China (Figure 2c,d). The particular interest may not be regarded as surprising, given the fact that the country has the second highest number of rabies cases [14], is the world’s largest administer of rabies vaccines [38], and has an emerging market economy [39]. However, very few to no patents are applied for in other high-risk rabies countries with large potential markets such as India and Nigeria [14]. A lack of innovation activity due to the countries’ innovation ecosystems could be another reason for the observed differences [40], though this is less likely considering that clinical trial sponsors do show an interest in India (Table 3). Thus, the results indicate that the number of patents is not solely related to market size and innovation potential of a country.

Literature suggests that among the influencing factors on patent activity are national and local patent policies. In China, the growing number of rabies patents coincides with an overall peak in patent applications that can be explained from the introduction of local patent subsidy programs [41]. The subsidies lower the costs of patenting and are known to incentivise applying for large numbers of patents [42] with little regard to the quality of these patents [43,44]. The results of the current study show that this is also the case for rabies-related patents, as Chinese patents score low on patent quality (Table 1). Following this argument, local patent systems of India and Nigeria could also explain the limited number of patent applications in these countries. Both countries signed the TRIPS agreements but provide little protection to owners of patent rights which refrains inventors from patenting their invention in these countries [45].

On a positive note, there is a high and increasing involvement of public stakeholders, including stakeholders from high-risk countries. Private stakeholders have dominated the rabies landscape with patent applications in low-risk countries (Figures 2D and 3) and traditionally sponsor late phase clinical trials [46]. Although private stakeholders file relatively many patents in high-risk countries compared to other stakeholders (Figure 4), the potential societal impact of these patents may still be...
limited if private stakeholders aim for profit-maximisation. The increased interest from public stakeholders indicates that innovation in the field of rabies becomes increasingly motivated by societal return as these stakeholders are generally more driven by altruistic motivations [47]. The interpretation is supported by our data showing that the majority of clinical trials investigate adjustments to existing rabies prophylaxes, which make these products more economical and thus suitable for addressing needs in high-risk settings [48].
The results should be seen in the light of some limitations that are related to the quality index that was developed for this study. The index uses cut-offs to categorise a patent as either low or high quality while neglecting a range of possibilities within the group of high-quality patents, such as the number of FCTs, the number of foreign applications and legal status. Dichotomising the continuous data results in a loss of information that may further differentiate between high-quality patents, but it adjusts for patent age and is also a well-established solution for analysing highly skewed data [49]. Importantly, the limitation is believed to be largely remedied by the use of multiple indicators. Another limitation of the index relates to the fact that all quality indicators were considered equally important. Our results show that high-quality patents stand out mainly by being filed in foreign jurisdictions as well as domestically (Table 1), which indicates that this indicator may warrant more weight than others. Likewise, it could be argued that less weight should be given to the indicator of being granted, since it is hard to tell whether or not a patent may still be granted in the future by merely looking at kind codes. The results of this study thus provide insights that can be used for optimisation of the research method.

Based on the results of our study we can conclude that no serious improvements of the product pipeline should be expected, despite increased international attention since the 2000s. A recent growth in patent applications seems promising at first glance, but appears to entail primarily low-quality patents. Since these patents do not reflect real market potential they cannot be regarded as an incentive for others to invest in the development of rabies-specific countermeasures. Some hope for a more economical medical intervention against rabies can be derived from clinical research sponsored by stakeholders from high-risk countries, since this has already led to the market introduction of products like Rabishield, Vaxirab and KamRAB. Policy makers are encouraged to use the information provided in this article to make informed decisions on the allocation of funding and to monitor the results of clinical trials.

### Table 2: Top 3 patent applicants per time period. The table shows a shift from private (blue) to public (green) stakeholders as key applicant and a decline in the share of the key applicants in the total number of applications

| Period       | Total | #1                      | #2                          | #3                          |
|--------------|-------|-------------------------|-----------------------------|-----------------------------|
| 1948–1957    | 5     | American Cyanamid [US]  | 80% Eli Lilly and Company [US] 20% Parke-Davis and Company [US] | 15%                          |
| 1958–1967    | 20    | American Cyanamid [US]  | 40% DOW Chemical Company [US] 25% Parke-Davis and Company [US] | 10%                          |
| 1968–1977    | 21    | American Home Products [US] 14% Eli Lilly and Company [US] | 10% Institut Mérix [FR] Laboratoire Roger Bellon [FR] | 9% |
| 1978–1987    | 32    | Cutter Laboratories [US] | 13% Behringwerke [DE] Transgene [FR] | 7% |
| 1988–1997    | 59    | Chemo-Sero-Therapeutic Research Institute [JP] 6% | Wistar Institute [US] 5% Thomas Jefferson University [US] | 4% |
| 1998–2007    | 115   | Academy of Military Medical Sciences [CN] 5% | Thomas Jefferson University [US] 4% Wistar Institute [US] | 3% |
| 2008–2017†   | 331   | Academy of Military Medical Sciences [CN] 5% | Chinese Academy of Agricultural Sciences [CN] 3% Huazhong Agricultural University [CN] | 2% |

†Until March 2017.

### Table 3: Key sponsor of clinical trials

| Clinical trials | Sponsor | Origin | Patents |
|-----------------|---------|--------|---------|
| 9               | Novartis | CH     | 1       |
| 8               | Queen Saovabha Memorial Institute | TH | 0       |
| 7               | Crucell Holland | NL | 4       |
| 7               | Sanofi Pasteur | FR | 3       |
| 5               | Beijing Center for Disease Control and Prevention | CN | 0       |
| 4               | Serum Institute of India | IN | 0       |
| 4               | Zydus Cadila | IN | 2       |
| 3               | Kempegowda Institute of Medical Sciences | IN | 0       |
| 2               | Cadila Pharmaceuticals | IN | 0       |
| 2               | CureVac | DE | 3       |
| 2               | GlaxoSmithKline | UK | 0       |
| 2               | Chemo-Sero-Therapeutic Research Institute | JP | 5       |
| 2               | Upstate Medical University | US | 0       |
| 2               | Institute of Tropical Medicine | BE | 0       |
| 2               | Yisheng Biopharma | SG | 2       |
| 2               | Human Biologicals Institute | IN | 0       |
| 2               | Mahidol University | TH | 0       |
| 2               | Kamada | IL | 0       |
policy outcomes [24]. Additionally, the research method provided in this study may inspire other researchers to better inform stakeholder groups with analyses of readily available data.

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Supporting Information
Additional Supporting Information may be found in the online version of this article:

Appendix S1. List of Cooperative Patent Classification (CPC) codes.
Appendix S2. List of kind codes and legal status.

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