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(54) Titre : COMPOSITION D'UN CONJUGUE POLYSACCHARIDE-PROTEINE PNEUMOCOCCIQUE MULTIVALENT
(54) Title: MULTIVALENT PNEUMOCOCCAL POLYSACCHARIDE-PROTEIN CONJUGATE COMPOSITION

(57) Abrégé/Abstract:
Provided is an immunogenic composition comprising 13 different polysaccharide-protein conjugates. Each of the conjugates comprises a capsular polysaccharide prepared from a different serotype Streptococcus pneumoniae conjugated to a carrier protein, that is, 12 serotypes selected from the group consisting of 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F and serotype 2 or 9N. The immunogenic composition formulated into a vaccine comprising an aluminum-based adjuvant increases coverage with respect to pneumococcal diseases in infants and children.

ABSTRACT

Provided is an immunogenic composition comprising 13 different polysaccharide-protein conjugates. Each of the conjugates comprises a capsular polysaccharide prepared from a different serotype Streptococcus pneumoniae conjugated to a carrier protein, that is, 12 serotypes selected from the group consisting of 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F and serotype 2 or 9N. The immunogenic composition formulated into a vaccine comprising an aluminum-based adjuvant increases coverage with respect to pneumococcal diseases in infants and children.

MULTIVALENT PNEUMOCOCCAL POLYSACCHARIDE-PROTEIN CONJUGATE COMPOSITION

TECHNICAL FIELD

The present invention relates to a multivalent immunogenic composition comprising: 13 distinct polysaccharide-protein conjugates prepared by conjugating capsular polysaccharides derived from 12 *Streptococcus pneumoniae* serotypes, 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F and *Streptococcus pneumoniae* serotype 2 or 9N to a carrier protein such as CRM_{197}. The present invention relates generally to the field of medicine, and specifically to microbiology, immunology, vaccines and the prevention of pneumococcal disease in infants, children, and adults by immunization.

BACKGROUND ART

Streptococcus pneumoniae is a leading cause of pneumonia. According to the 2010 Mortality Trend by Cause published by The National Statistical Office, pneumonia was one of the top 10 causes of death, with 14.9 deaths per 100,000 people, which is an 82.9% increase from 2000. The World Health Organization (WHO) also estimated in 2012 that globally, 476,000 HIV negative children 5 years of age or younger died from infection by *Streptococcus pneumoniae*, which accounts for 5% of all-cause child mortality for children under five.

In 1977, Dr. Robert Austrian developed a 14-valent pneumococcal polysaccharide vaccine in order to prevent pneumococcal disease and then the vaccine evolved to a 23-valent polysaccharide vaccine. The multivalent pneumococcal polysaccharide vaccines have proved valuable in preventing pneumococcal disease in elderly adults and high-risk patients. However, infants and young children respond poorly to most pneumococcal polysaccharides due to a T-cell independent immune response. The 7-valent pneumococcal conjugate vaccine (7vPnC, Prevnar®) contains capsular polysaccharides from the seven most prevalent serotypes 4, 6B, 9V, 14, 18C, 19F and 23F. Since approved in the U.S. in 2000, Prevnar has been demonstrated to be highly immunogenic and effective against invasive disease and otitis media in infants and young children. This vaccine is now approved in about 80 countries around the world.

Prevnar covers approximately 80-90%, 60-80%, and 40-80% of invasive pneumococcal disease (IPD) in the US, Europe, and other regions of the world, respectively. As expected, surveillance data gathered in the years following Prevnar's introduction has clearly demonstrated a reduction of invasive pneumococcal disease caused by the serotypes covered by Prevnar in the US. However, the coverage of the serotypes was limited in some regions and invasive pneumococcal diseases caused by the serotypes that are not covered by Prevnar, in particular 19A, have increased.

The Advisory Committee on Immunization Practices (ACIP) announced in February, 2010 its recommendation of a newly approved 13-valent pneumococcal conjugate vaccine (PCV-13) for vaccination. PCV-13 is a pneumococcal conjugate vaccine comprising six additional serotypes (1, 3, 5, 6A, 7F, 19A) in addition to the seven serotypes (4, 6B, 9V, 14, 18C, 19F, 23F) comprised in Prevnar. According to the US Active Bacterial Core surveillance (ABCs), a total of 64% of the IPD cases known as the pathogenic serotypes among children of 5 years of age or younger is covered by PCV-13. In 2007, only 70 cases among 4600 IPD cases in children 5 years of age or younger were covered by PCV7, while 2900 cases were covered by PCV-13, which accounts for the majority. Now, a 15-valent pneumococcal conjugate vaccine is under development which covers additional serotypes whose incidence increases with serotype replacement.

DETAILED DESCRIPTION OF THE INVENTION

Accordingly, the present invention provides a multivalent immunogenic composition for the prevention of pneumococcal disease in infants, children and adults, comprising capsule polysaccharides derived from 13 pneumococcal serotypes including serotype 2 or 9N. Specifically, the present invention provides a 13-valent pneumococcal conjugate (PCV-13) composition comprising serotype 2 or 9N, and serotypes 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F, and 23F.

TECHNICAL SOLUTION

According to an aspect of the present invention, provided is a multivalent immunogenic composition, comprising 13 distinctive polysaccharide-protein conjugates together with a physiologically acceptable vehicle, wherein each of the conjugates comprises a capsular polysaccharide derived from a different serotype of Streptococcus pneumoniae conjugated to a carrier protein, and the capsular polysaccharides are prepared from 12 serotypes selected from the group consisting of 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F, and serotype 2 or 9A.

In the multivalent immunogenic composition according to the present invention, the carrier protein may be CRM_{197}. The multivalent immunogenic composition according to the present invention may further comprise an adjuvant, for example, an adjuvant comprising an aluminum-based adjuvant. The adjuvant may be selected from the group consisting of aluminum phosphate, aluminum sulfate and aluminum hydroxide, and preferably, aluminum phosphate.

According to another aspect of the present invention, provided is a pharmaceutical composition for inducing an immune response to a Streptococcus pneumoniae capsular polysaccharide conjugate, comprising an immunologically effective amount of said immunogenic composition.

In one embodiment, the pharmaceutical composition may be an immunogenic composition formulated to contain: 2 μg of polysaccharide of each serotype, except for 6B at 4 μg; approximately 34 μg CRM_{197} carrier protein; 0.125 mg of elemental aluminum (0.5 mg aluminum phosphate) adjuvant; and sodium chloride and sodium succinate buffer as excipients.

TECHNICAL EFFECT

The multivalent-immunogenic composition according to the present invention comprises capsular polysaccharides derived from 13 distinctive pneumococcal serotypes including serotype 2 or 9N, thereby leading to an elevated serum IgG titer and functional antibody activity. Therefore, the multivalent immunogenic composition

according to the present invention can be advantageously used for prevention of pneumocccal disease in infants, children and adults.

MODE OF INVENTION

Serotype replacement has been made by some serotypes with antibiotic resistance and multiple drug resistance. In addition, regional differences in serotype distribution have led to differences in coverage of Prevnar by region (Harboe ZB, Benfield TL, Valentiner-Branth P, et al. Temporal Trends in Invasive Pneumococcal Disease and Pneumococcal Serotypes over 7 Decades. Clin Infect Dis 2010; 50:329-37). Thus, there is no reason to remove any of the serotypes in the existing pneumococcal conjugate vaccines. Rather, there is a need to further expand the coverage by addition of serotypes.

In 2008, the Pneumococcal Global Serotype Project (GSP) announced a report based on IPD data collected from 1980 to 2007, showing that, following serotype 18C, serotype 2 was the 11th highest incidence serotype among the top 20 global serotypes. In addition, Samir K. Saha et al. reported that serotype 2 may become a threat because serotype 2 has a high probability of causing pneumococcal meningitis in Bangladesh but is not included in any pneumococcal conjugate vaccine (Saha SK, Al Emran HM, Hossain B, Darmstadt GL, Saha S, et al. (2012) Streptococcus pneumoniae Serotype-2 Childhood Meningitis in Bangladesh: A Newly Recognized Pneumococcal Infection Threat. PLoS ONE 2012; 7(3): e32134). Thus, if serotype 2 is included in the pneumococcal conjugate vaccines, the number of pneumococcal diseases can be reduced and further be prepared for the serotype replacement that may occur with vaccination by PCV-13.

Pneumococcal serotypes show different distribution patterns by age of a subject. In particular, serotype 9N has been found to be relatively important in infants aged 0 to 23 months, who are subjects for vaccination by a pneumococcal conjugate vaccine, compared to children aged 24 to 59 months. Serotype 9N was the 14th most common serotype following the 13 serotypes included in PCV-13. This indicates that inclusion of serotype 9N will contribute to reduction in the incidence of pneumococcal diseases, in

particular among infants.

The present invention provides a multivalent immunogenic composition comprising 13 capsular polysaccharides included in Prevenar 13, one of which is replaced with serotype 2 or 9N. Specifically, the present invention provides a multivalent immunogenic composition, comprising: 13 distinct polysaccharide-protein conjugates, together with a physiologically acceptable vehicle, wherein each of the conjugates comprises a capsular polysaccharide from a different serotype of Streptococcus pneumoniae conjugated to a carrier protein, and the capsular polysaccharides are prepared from 12 serotypes selected from the group consisting of serotypes 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F, and serotype 2 or 9N.

Capsular polysaccharides may be prepared by standard techniques known to those of ordinary skill in the art. Capsular polysaccharides may be reduced in size in order to decrease the viscosity or increase the solubility of activated capsular polysaccharides. In the present invention, capsular polysaccharides are prepared from 12 serotypes selected from the group consisting of serotypes 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F of *Streptococcus pneumoniae,* and serotype 2 or 9N of *Streptococcus pneumoniae*. These pneumococcal conjugates are prepared by separate processes and formulated into a single dosage formulation. For example, *Streptococcus pneumoniae* of each serotype is grown in a soy-based medium and then each pneumococcal polysaccharide serotype is purified through centrifugation, precipitation, and ultra-filtration.

Carrier proteins are preferably proteins that are non-toxic and non-reactogenic and obtainable in sufficient amount and purity. Carrier proteins should be amenable to standard conjugation procedures. In the multivalent immunogenic composition of the present invention, the carrier protein may be CRM_{197}. CRM_{197} is a non-toxic variant (i.e., toxoid) of diphteria toxin isolated from cultures of *Corynebacterium diphteria* strain C7 (β197) grown on a casamino acids and yeast extract-based medium. CRM_{197} is purified through ultra-filtration, ammonium sulfate precipitation, and ion-exchange chromatography. Alternatively, CRM_{197} is prepared recombinantly in accordance with U.S. Patent No. 5,614,382.

Other diphteria toxoids are also suitable for use as carrier proteins. Other suitable carrier proteins include inactivated bacterial toxins such as tetanus toxoid, pertussis toxoid; cholera toxoid (WO2004/083251), E. coli LT, E. coli ST, and exotoxin A from *Pseudomonas aeruginosa.* Bacterial outer membrane proteins such as outer membrane complex c (OMPC), porins, transferrin binding proteins, pneumolysin, pneumococcal surface protein A (PspA), pneumococal adhesin protein (PsaA), C5a peptidase from Group A or Group B streptococcus, or *Haemophilus influenzae* protein D, can also be used. Other proteins, such as ovalbumin, keyhole limpet hemocyanin (KLH), bovine serum albumin (BSA) or purified protein derivative of tuberculin (PPD) can also be used as carrier proteins. Diphtheria toxin variants such as CRM_{173}, CRM_{228}, and CRM_{45} can also be used as a carrier protein.

In order to prepare polysaccharides for reaction with a carrier protein, purified polysaccharides are chemically activated. Once activated, each capsular polysaccharide is separately conjugated to a carrier protein to form a glycoconjugate. In one embodiment, each capsular polysaccharide is conjugated to the same carrier protein. The chemical activation of the polysaccharides and subsequent conjugation to the carrier protein are achieved by conventional means (for example, U.S. Pat. Nos. 4,673,574 and 4,902,506). Hydroxyl groups in the polysaccharides are oxidized to aldehyde groups by oxidizing agents such as periodates (including sodium periodate, potassium periodate, calcium periodate or periodic acid). The chemical activation leads to irregular oxidative degradation of adjacent hydroxyl groups. The conjugation is achieved by reductive amination. For example, the activated capsular polysaccharides and the carrier protein are reacted in the presence of a reducing agent such as sodium cyanoborohydride. Unreacted aldehyde groups can be removed by addition of a strong oxidizing agent.

After conjugation of the capsular polysaccharide to the carrier protein, the polysaccharide-protein conjugates may be purified (enriched with respect to the polysaccharide-protein conjugate) by a variety of techniques. These techniques include concentration/diafiltration, column chromatography, and depth filtration. The purified polysaccharide-protein conjugates are mixed to formulate the immunogenic composition of the present invention, which can be used as a vaccine. Formulation of the

immunogenic composition of the present invention can be accomplished using methods recognized in the pertaining art. For instance, the 13 individual pneumococcal conjugates can be formulated with a physiologically acceptable vehicle to prepare the composition. Examples of such vehicles include, but are not limited to, water, buffered saline, polyols (e.g., glycerol, propylene glycol, liquid polyethylene glycol) and dextrose solutions.

In one embodiment, the immunogenic composition of the present invention may comprise one or more adjuvants. As defined herein, an "adjuvant" refers to a substance that serves to enhance the immunogenicity of an immunogenic composition of the present invention. Thus, adjuvants are often provided to boost the immune response and are well known to those of ordinary skill in the art. Suitable adjuvants to enhance effectiveness of the composition include, but are not limited to:

(1) aluminum salts (alum), such as aluminum hydroxide, aluminum phosphate, aluminum sulfate, etc.;

(2) oil-in-water emulsion formulations (with or without other specific immunostimulating agents such as muramyl peptides (as defined below) or bacterial cell wall components), such as, (a) MF59 (WO 90/14837), containing 5% Squalene, 0.5% Tween 80, and 0.5% Span 85 (optionally containing various amounts of MTP-PE (see below, although not required), formulated into submicron particles using a microfluidizer such as Model 110Y microfluidizer (Microfluidics, Newton, MA), (b) SAF, containing 10% Squalene, 0.4% Tween 80, 5% pluronic-blocked polymer L121, and thr-MDP (see below), either microfluidized into a submicron emulsion or vortexed to generate a larger particle size emulsion, and (c) Ribi™ adjuvant system (RAS), (Corixa, Hamilton, MT) containing 2% Squalene, 0.2% Tween 80, and one or more bacterial cell wall components selected from the group consisting of 3-O-deaylated monophosphory lipid A (MPL™) described in U.S. Patent No. 4,912,094 (Corixa), trehalose dimycolate (TDM), and cell wall skeleton (CWS), preferably MPL + CWS (Detox™);

(3) saponin adjuvants, such as Quil A or STIMULON™ QS-21 (Antigenics, Framingham, MA) (U.S. Patent No. 5,057,540) or particles generated therefrom such as ISCOMs (immunostimulating complexes);

(4) bacterial lipopolysaccharides, synthetic lipid A homologs such as aminoalkyl

glucosamine phosphate compounds (AGP), or derivatives or homologs thereof, which are available from Corixa, and which are described in U.S. Patent No. 6,113,918; one such AGP is 2-[(R)-3-Tetradecanoyloxytetradecanoylamino]ethyl 2-Deoxy-4-0-phosphono-3-0-[(R)-3-tetradecanoyloxytetradecanoyl]-2-[(R)-3-tetradecanoyloxytetradecanoylamino]-b-D-glucopyranoside, which is also known as 529 (formerly known as RC529), which is formulated as an aqueous form or as a stable emulsion,

(5) synthetic polynucleotides such as oligonucleotides containing CpG motif(s) (U.S. Patent No. 6,207,646);

(6) cytokines, such as interleukins (e.g., IL-1, IL-2, IL-4, IL-5, IL-6, IL-7, IL-12, IL-15, IL-18, etc.), interferons (e.g., gamma interferon), granulocyte macrophage colony stimulating factor (GM-CSF), macrophage colony stimulating factor (M-CSF), tumor necrosis factor (TNF), costimulatory molecules B7-1 and B7-2, etc.;

(7) detoxified mutants of a bacterial ADP-ribosylating toxin such as a cholera toxin (CT) either in a wild-type or mutant form, for example, where the glutamic acid at amino acid position 29 is replaced by another amino acid, preferably a histidine, in accordance with WO 00/18434 (see also WO 02/098368 and WO 02/098369), a pertussis toxin (PT), or an E. coli heat-labile toxin (LT), particularly LT-K63, LT-R72, CT-S109, PT-K9/G129 (see, e.g., WO 93/13302 and WO 92/19265); and

(8) complement components such as trimer of complement component C3d.

Muramyl peptides include, but are not limited to, N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP) and N-acetyl-normuramyl-L-alanine-2-(1'-2' dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy)-ethylamine (MTP-PE).

In a specific embodiment, an aluminum salt is used as an adjuvant. An aluminum salt adjuvant may be an alum-precipitated vaccine or alum-adsorbed vaccine. Aluminum salts include, but are not limited to, hydrated alumina, alumina trihydrate (ATH), aluminum hydrate, aluminum trihydrate, Alhydrogel, Superfos, Amphojel, aluminum hydroxide (III), aluminum hydroxyphosphate sulfate(Aluminum Phosphate Adjuvant (APA)), and amorphous alumina. APA is a suspension of aluminum hydroxyphosphate. If aluminum chloride and sodium phosphate are mixed in a ratio of 1:1, aluminum hydroxyphosphate sulfate is precipitated. The precipitates are sized to

2-8μm by using a high shear mixer and dialyzed with physiological saline, followed by sterilization. In one embodiment, commercially available $Al(OH)_3$ (for example, Alhydrogel or Superfos) is used to adsorb proteins. 50-200 g of protein can be adsorbed per 1 mg of aluminum hydroxide, and this ratio is dependent on an isoelectric point (pI) of proteins and pH of solvents. Proteins of low pI are strongly adsorbed compared to proteins of high pI. Aluminum salts form an antigen depot that slowly releases antigens over 2 to 3 weeks, nonspecifically activating phagocytes, complements, and the congenital immune system.

The present invention provides a pharmaceutical composition (for example, a vaccine formulation) for inducing an immune response to *Streptococcus pneumoniae* capsular polysaccharide conjugates, comprising an immunologically effective amount of the immunogenic composition.

The vaccine formulation of the present invention may be used to protect or treat a human susceptible to pneumococcal infection, by administering the vaccine via a systemic or mucosal route. As defined herein, the term "effective amount" refers to the amount required to induce antibodies to a level sufficient to significantly reduce the probability of Streptococcus pneumoniae infection or severity thereof. These administrations can include injection via the intramuscular, intraperitoneal, intradermal or subcutaneous routes; or mucosal administration to the oral/alimentary, respiratory or genitourinary tracts.

In one embodiment, intranasal administration is used for the treatment of pneumonia or otitis media since nasopharyngeal carriage of pneumococci can be more effectively prevented, thus attenuating infection at its initial stage. The amount of the conjugates in each vaccine dose is selected as an amount that induces an immunoprotective response without significant, adverse effects. Such an amount can vary depending upon the pneumococcal serotype. Generally, each dose will comprise 0.1 to 100 μg of polysaccharide, particularly 0.1 to 10 μg, and more particularly 1 to 5 μg. Optimal amounts of components for a particular vaccine can be determined by standard studies involving observation of appropriate immune responses in subjects. For example, the amount for vaccination of a human subject can be determined by extrapolating the animal test result. In addition, the dosage can be determined empirically.

In a particular embodiment of the present invention, the vaccine composition is a sterile liquid formulation of pneumococcal capsular polysaccharides of 12 serotypes selected from the group consisting of serotypes 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F, and 23F, and serotype 2 or 9N, individually conjugated to CRM_{197}. Each 0.5 mL dose may be formulated to contain: 2 µg of polysaccharide of each serotype, except for 6B at 4 µg; approximately 34 µg CRM_{197} carrier protein; 0.125 mg of elemental aluminum (0.5 mg aluminum phosphate) adjuvant; and sodium chloride and sodium succinate buffer as excipients. The liquid may be filled into a single dose syringe without any preservative. Upon shaking, the liquid becomes a vaccine of a homogeneous, white suspension ready for intramuscular administration.

In a further embodiment, the composition of the present invention can be administered in a single administration. For example, the vaccine composition of the present invention can be administered 2, 3, 4, or more times at appropriately spaced intervals, such as, a 1, 2, 3, 4, 5, or 6 month interval or a combination thereof. The immunization schedule can follow that designated for the Prevnar vaccine. For example, the routine schedule for infants and toddlers against invasive disease caused by S. pneumoniae is at 2, 4, 6 and 12-15 months of age. Thus, in this aspect, the composition is administered 4 times, i.e., at 2, 4, 6, and 12-15 months of age.

The compositions of the present invention may also include one or more proteins from *Streptococcus pneumoniae*. Examples of *Streptococcus pneumoniae* proteins suitable for inclusion in the composition include those identified in International Patent Application WO02/083855, as well as those described in International Patent Application WO02/053761.

The composition of the present invention can be administered to a subject via one or more administration routes known to one of ordinary skill in the art such as a parenteral, transdermal, transmucosal, intranasal, intramuscular, intraperitoneal, intracutaneous, intravenous, or subcutaneous route and be formulated accordingly. In one embodiment, the composition of the present invention may be administered as a liquid formulation by intramuscular, intraperitoneal, subcutaneous, intravenous, intraarterial, or transdermal injection or respiratory mucosal injection. The liquid formulation for injection may include a solution or the like.

The composition of the present invention can be formulated in a form of a unit dose vial, multiple dose vial, or pre-filled syringe. A pharmaceutically acceptable carrier for a liquid formulation includes aqueous or nonaqueous solvent, suspension, emulsion or oil. Examples of a nonaqueous solvent include propylene glycol, polyethylene glycol, and ethyl oleate. Aqueous carriers include water, alcohol/aqueous solvent, emulsion, or suspension, physiological saline, and buffer solution. Examples of oil include vegetable or animal oil, peanut oil, soybean oil, olive oil, sunflower oil, liver oil, synthetic oil such as marine oil, and lipids obtained from milk or eggs. The pharmaceutical composition may be isotonic, hypertonic or hypotonic. However, it is preferable that the pharmaceutical composition for infusion or injection is basically isotonic. Thus, isotonicity or hypertonicity may be advantageous for storage of the composition. When the pharmaceutical composition is hypertonic, the composition can be diluted to isotonicity before administration. A tonicity agent may be an ionic tonicity agent such as salt or a non-ionic tonicity agent such as carbohydrate. The ionic tonicity agent includes sodium chloride, calcium chloride, potassium chloride, and magnesium chloride, but is not limited thereto. The non-ionic tonicity agent includes sorbitol and glycerol, but is not limited thereto. Preferably, at least one pharmaceutically acceptable buffer is included. For example, when the pharmaceutical composition is an infusion or injection, it is preferable to be formulated in a buffer with a buffering capacity at pH 4 to 10, such as pH 5-9 or 6-8. The buffer can be selected from the group consisting of TRIS, acetate, glutamate, lactate, maleate, tartrate, phosphate, citrate, carbonate, glycinate, histidine, glycine, succinate, and triethanolamine buffer solution.

In particular, if the pharmaceutical composition is for parenteral administration, a buffer may be selected from those acceptable to the United States Pharmacopeia (USP). For example, the buffer may be selected from the group consisting of monobasic acid such as acetic acid, benzoic acid, gluconic acid, glyceric acid, and lactic acid; dibasic acid such as aconitic acid, adipic acid, ascorbic acid, carbonic acid, glutamic acid, malic acid, succinic acid, and tartaric acid; polybasic acid such as citric acid and phosphoric acid; and base such as ammonia, diethanolamine, glycine, triethanolamine, and TRIS. For parenteral administration, vehicles (for subcutaneous, intravenous, intraarticular, and intramuscular injection) include sodium chloride solution, Ringer's dextrose solution,

dextrose and sodium chloride, lactated Ringer's solution and fixed oils. Vehicles for intravenous administration include Ringer's dextrose solution or a similar dextrose based infusion solution, nutritional supplements and electrolyte supplements. The example includes a sterile liquid such as water and oil, with or without a surface active agent and a pharmaceutically acceptable adjuvant. Generally, water, physiological saline, dextrose solution, related sugar solution, and glycols such as propylene glycol or polyethylene glycol, in particular, polysorbate 80, are suitable for an injection. Examples of oil include animal and vegetable oil, peanut oil, soybean oil, olive oil, sunflower oil, liver oil, synthetic oil such as marine oil and lipids from milk or eggs.

The formulation of the present invention may comprise surface active agents. Preferably, polyoxyethylene sorbitan ester (generally referred to as Tweens™), in particular, polysorbate 20 and polysorbate 80; copolymers (such as DOWFAX™) of ethylene oxide (EO), propylene oxide (PO), butylenes oxide (BO); octoxynols with a different number of repeats of ethoxy(oxy-1,2-ethanediyl) group, in particular, octoxynol-9(Triton™-100); ethylphenoxypolyethoxyethanol (IGEPAL CA-630/NP-40); phospholipid such as lecithin; nonylphenol ethoxylate such as Tergitol™ NP series; lauryl, cetyl, stearyl, oleyl alcohol-derived polyoxyethylene fatty ether (Brij™ surfactant), in particular, triethyleneglycol monolauryl ether (Brij™ 30); sorbitan ether known as SPAN™, in particular, sorbitan trioleate (Span™ 85) and sorbitan monolaurate but without limitation thereto. Tween™ 80 is preferably comprised in an emulsion.

Mixtures of surface active agents such as Tween™ 80/Span™ 85 can be used. A combination of polyoxyethylene sorbitan ester such as Tween™ 80 and octoxynol such as Triton™ X-100 is also suitable. A combination of Laureth 9 and Tween and/or octoxynol is also suitable. Preferably, the amount of polyoxyethylene sorbitan ester (such as Tween™ 80) included is 0.01% to 1% (w/v), in particular 0.1%; the amount of octylphenoxy polyoxyethanol or nonylphenoxy polyoxyethanol (such as ™ X-100) included is 0.001% to 0.1% (w/v), in particular 0.005% to 0.02%; and the amount of polyoxyethylene ether (such as laureth 9) included is 0.1% to 20% (w/v), possibly 0.1% to 10%, in particular 0.1% to 1% or about 0.5%. In one embodiment, the pharmaceutical composition is delivered via a release control system. For example, intravenous infusion, transdermal patch, liposome, or other routes can be used for

administration. In one aspect, macromolecules such as microsphere or implant can be used.

The above disclosure generally describes the present invention. A more complete understanding can be obtained by reference to the following specific examples. These examples are described solely for the purpose of illustration and are not intended to limit the scope of the present invention.

EXAMPLES

Example 1. Preparation of S. pneumoniae Capsular Polysaccharide

Cultivation of S. pneumoniae and purification of capsular polysaccharides were conducted as known to one of ordinary skill in the art. S. pneumoniae serotypes were obtained from the American Type Culture Collection (ATCC). S. pneumoniae were characterized by capsules and immobility, Gram-positivity, lancet-shaped diplococcus and alpha hemolysis in a blood agar medium. Serotypes were identified by Quelling test using specific anti-sera (US Patent No. 5,847,112).

Preparation of Cell Banks

Several generations of seed stocks were generated in order to expand the strain and remove components of animal origin (generations F1, F2, and F3). Two additional generations of seed stocks were produced. The first additional generation was made from an F3 vial, and the subsequent generation was made from a vial of the first additional generation. Seed vials were stored frozen (≤-70℃) with synthetic glycerol as a cryopreservative. For preparation of cell banks, all cultures were grown in a soy-based medium. Prior to freezing, cells were concentrated by centrifugation, spent medium was removed, and cell pellets were re-suspended in a fresh medium containing a cryopreservative (such as synthetic glycerol).

Inoculation

Cultures from the working cell bank were used to inoculate seed bottles containing a soy-based medium. The seed bottle was used to inoculate a seed fermentor containing a soy-based medium.

Seed Fermentation

Seed fermentation was conducted in a seed fermentor with the temperature and pH controlled. After the target optical density was reached, the seed fermentor was used to inoculate the production fermentor containing the soy- based medium.

Production Fermentation

Production fermentation is the last step in fermentation. Temperature, pH and agitation speed were controlled.

Inactivation

When the growth stopped, the fermentation was terminated by addition of an inactivator. After inactivation, the contents in the fermentor were cooled and the pH thereof was adjusted.

Purification

Broth from the fermentor was centrifuged and filtered to remove bacterial cell debris. Several rounds of concentration/diafiltration operations, precipitation/elution, and depth filtration were used to remove contaminants and purify capsular polysaccharides.

Example 2. Preparation of S. pneumoniae Capsular Polysaccharide-CRM_{197} Conjugate

Polysaccharides of different serotypes were activated following different pathways and then conjugated to CRM_{197}. The activation process comprises reduction of the size of capsular polysaccharides to the target molecular weights, chemical activation and buffer exchange via ultrafiltration. Purified CRM_{197} is conjugated to activated capsular

polysaccharides, and the conjugates are purified using ultrafiltration and finally filtered through a 0.22 μm filter. The process parameters such as pH, temperature, concentration and time are as follows.

(1) Activation

Step 1

Polysaccharides of each serotype were diluted with water for injection, sodium acetate, and sodium phosphate to a final concentration in a range of 1.0 to 2.0 mg/mL. For serotype 1, sodium hydroxide (0.05M final base concentration) was added and the solution was incubated at 50°C±2°C. Then, the solution was cooled to 21 to 25°C and the hydrolysis was stopped by adding 1M HCl until a target pH of 6.0±0.1 was reached. For serotype 3, HCl (0.01M final acid concentration) was added and the solution was incubated at 50°C±2°C. Then, the solution was cooled to 21 to 25°C and the hydrolysis was stopped by adding 1M sodium phosphate until a target pH of 6.0±0.1 was reached. For serotype 4, HCl (0.1M final acid concentration) was added and the solution was incubated at 45°C±2°C. Then, the solution was cooled to 21 to 25°C and the hydrolysis was stopped by adding 1M sodium phosphate until a target pH of 6.0±0.1 was reached. For serotype 6A, glacial acetic acid (0.2M final acid concentration) was added and the solution was incubated at 60°C±2°C. Then, the solution was cooled to 21 to 25°C and the hydrolysis was stopped by adding 1M sodium hydroxide until a target pH of 6.0±0.1 was reached. For serotype 14 and 18C, glacial acetic acid (0.2M final acid concentration) was added and the solution was incubated at 94°C±2°C. Then, the solution was cooled to 21 to 25°C and the hydrolysis was stopped by adding 1M sodium phosphate until a target pH of 6.0±0.1 was reached.

Step 2: Periodate reaction

The molar equivalents of sodium periodate required for activation of pneumococcal saccharides was determined using total saccharide content. With thorough mixing, the oxidation reaction was allowed to proceed for between 16 to 20

hours at 21 - 25°C for all serotypes except 1, 7F, and 19F, for which the temperature was ≤ 10°C.

Step 3: Ultrafiltration

The oxidized saccharide was concentrated and diafiltered with water for injection (WFI) in a 100 kDa MWCO ultrafilter (30kDa ultrafilter for serotype 1 and 5 kDa ultrafilter for serotype 18C). Diafiltration was accomplished using 0.9% sodium chloride solution for serotype 1, 0.01M sodium acetate buffer (pH 4.5) for serotype 7F, and 0.01M sodium phosphate buffer (pH 6.0) for serotype 19F. The permeate was discarded and the retentate was filtered through a 0.22 µm filter

Step 4: Lyophilization

For serotypes 3, 4, 5, 9N, 9V, and 14, the concentrated saccharides were mixed with CRM_{197} carrier proteins, filled into glass bottles, lyophilized and then stored at -25° ± 5°C.

For serotypes 2, 6A, 6B, 7F, 19A, 19F, and 23F, a specified amount of sucrose was added which was calculated to achieve a 5% ± 3% sucrose concentration in the conjugation reaction mixture. Serotypes 1 and 18C did not require any addition of sucrose. The concentrated saccharide was then filled into glass bottles, lyophilized and then stored at -25° ± 5°C.

(2) Conjugation process

Aqueous conjugation was conducted for serotypes 1, 3, 4, 5, 9N, 9V, 14, and 18C, and DMSO conjugation was conducted for serotypes 2, 6A, 6B, 7F, 19A, 19F and 23F.

Step 1: Dissolution

Aqueous Conjugation

For serotypes 3, 4, 5, 9N, 9V and 14, the lyophilized activated saccharide-CRM_{197} mixture was thawed and equilibrated at room temperature. The lyophilized activated

saccharide-CRM_{197} was then reconstituted in a 0.1M sodium phosphate buffer at a typical ratio for each serotype. For serotypes 1 and 18C, the lyophilized saccharide was reconstituted in a solution of CRM_{197} in 1 M dibasic sodium phosphate at a typical ratio of 0.11 L of sodium phosphate per 1 L of CRM_{197} solution.

Dimethyl sulfoxide (DMSO) Conjugation

The lyophilized activated saccharides of serotypes 2, 6A, 6B, 7F, 19A, 19F, 23F and the lyophilized CRM_{197} carrier protein were equilibrated at room temperature and reconstituted in DMSO.

Step 2: Conjugation Reaction

Aqueous Conjugation

For serotypes 1, 3, 4, 5, 9N, 9V, 14 and 18C, the conjugation reaction was initiated by adding sodium cyanoborohydride solution (100 mg/mL) to achieve 1.0 - 1.2 moles sodium cyanoborohydride per mole of saccharide. The reaction mixture was incubated for 44 - 96 hours at 23℃ to 37℃. The temperature and reaction time were adjusted by serotype. The temperature was then reduced to 23° ± 2°C and sodium chloride 0.9% was added to the reactor. Sodium borohydride solution (100 mg/mL) was added to achieve 1.8 - 2.2 molar equivalents of sodium borohydride per mole saccharide. The mixture was incubated for 3 - 6 hours at 23° ± 2°C. This procedure led to reduction of any unreacted aldehydes present on the saccharides. The mixture was diluted with sodium chloride 0.9% and the diluted conjugation mixture was filtered using a 1.2 µm pre-filter into a holding vessel.

DMSO conjugation

For serotypes 2, 6A, 6B, 7F, 19A, 19F and 23F, activated saccharide and CRM_{197} carrier protein were mixed at a ratio in a range of 0.8 g - 1.25 g saccharide/g CRM_{197}. The conjugation reaction was initiated by adding the sodium cyanoborohydride solution

(100mg/mL) at a ratio of 0.8 - 1.2 molar equivalents of sodium cyanoborohydride to one mole activated saccharide. WFI was added to the reaction mixture to a target of 1 % (v/v), and the mixture was incubated for 11 - 27 hours at 23° ± 2°C. Sodium borohydride solution, 100 mg/mL (typical 1.8 - 2.2 molar equivalents sodium borohydride per mole activated saccharide) and WFI (target 5% v/v) were added to the reaction and the mixture was incubated for 3 - 6 hours at 23° ± 2°C. This procedure led to reduction of any unreacted aldehydes present on the saccharides. Then, the reaction mixture was diluted with sodium chloride 0.9%, and the diluted conjugation mixture was filtered using a 1.2 µm pre-filter into a holding vessel.

Step 3: Ultrafiltration

The diluted conjugate mixture was concentrated and diafiltered on a 100 kDa MWCO ultrafiltration filter with a minimum of 20 volumes of 0.9% sodium chloride or buffer. The permeate was discarded.

Step 4: Sterile Filtration

The retentate after the 100 kDa MWCO diafiltration was filtered through a 0.22 µm filter. In-process controls (saccharide content, free protein, free saccharide, and residual cyanide; and in the case of DMSO conjugation, residual DMSO is additionally checked) were performed on the filtered product. In-process controls on filtered retentate were performed to determine whether additional concentration, diafiltration, and/or dilution were needed. As necessary, the filtered conjugate was diluted with 0.9% sodium chloride to achieve a final concentration of less than 0.55 g/L. Release tests for saccharide content, protein content and saccharide:protein ratio were performed at this stage. Finally, the conjugate was filtered (0.22 µm) and a release test (appearance, free protein, free saccharide, endotoxin, molecular size determination, residual cyanide, residual DMSO, saccharide identity and CRM_{197} identity) was performed. The final bulk concentrated solution was stored at 2 - 8°C.

Example 3. Formulation of a Multivalent Pneumococcal Conjugate Vaccine

The required volumes of final bulk concentrates were calculated based on the batch volume and the bulk saccharide concentrations. After the required amounts of the 0.85% sodium chloride (physiological saline), polysorbate 80 and succinate buffer were added to the pre-labeled formulation vessel, bulk concentrates were added. The preparation was then thoroughly mixed and sterile filtered through a 0.22 µm membrane. The formulated bulk was mixed gently during and following the addition of bulk aluminum phosphate. The pH was checked and adjusted if necessary. The formulated bulk product was stored at 2-8℃. The product contained, in a 0.5 ml volume, 2 µg of poysaccharide of each serotype, except for 6B at 4 µg; approximately 32 µg CRM_{197} carrier protein; 0.125 mg of elemental aluminum (0.5 mg aluminum phosphate) adjuvant; about 4.25 mg of sodium chloride; about 295 µg of sodium succinate buffer; and about 100 µg of polysorbate 80.

CLAIMS:

1. A multivalent immunogenic composition, consisting of:

13 distinct polysaccharide-protein conjugates, together with a physiologically acceptable vehicle and an adjuvant,

wherein each of the polysaccharide-protein conjugates comprises a capsular polysaccharide from a different serotype of Streptococcus pneumoniae conjugated to CRM_{197} carrier protein, and wherein:

(1) one of the capsular polysaccharides is prepared from serotype 2 or 9N; and

(2) the remaining twelve capsular polysaccharides are prepared from serotypes selected from the group consisting of 1, 3, 4, 5, 6A, 6B, 7F, 9V, 14, 18C, 19A, 19F and 23F.

2. The multivalent immunogenic composition of claim 1, wherein the adjuvant is an aluminum-based adjuvant.

3. The multivalent immunogenic composition of claim 2, wherein the adjuvant is selected from the group consisting of aluminum phosphate, aluminum sulfate and aluminum hydroxide.

4. The multivalent immunogenic composition of claim 3, wherein the adjuvant is aluminum phosphate.

5. A pharmaceutical composition for inducing an immune response to Streptococcus pneumoniae capsular polysaccharide conjugates, comprising an immunologically effective amount of the multivalent immunogenic composition of any one of claims 1 to 4.

6. The pharmaceutical composition of claim 5, wherein the multivalent immunogenic composition is a single 0.5 ml dose formulated to contain:

2 µg of polysaccharide of each serotype, except for 6B at 4 µg;

approximately 34 µg of the CRM_{197} carrier protein;

0.125 mg of elemental aluminum (0.5 mg aluminum phosphate) adjuvant; and

sodium chloride and sodium succinate buffer as excipients.

7. The pharmaceutical composition of claim 6, wherein the adjuvant is 0.5 mg aluminum phosphate adjuvant.