INTERNATIONAL COMMITTEE OF MILITARY MEDICINE
COMITÉ INTERNATIONAL DE MÉDECINE MILITAIRE

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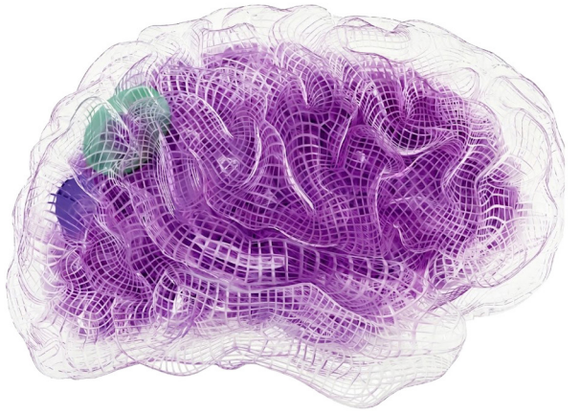

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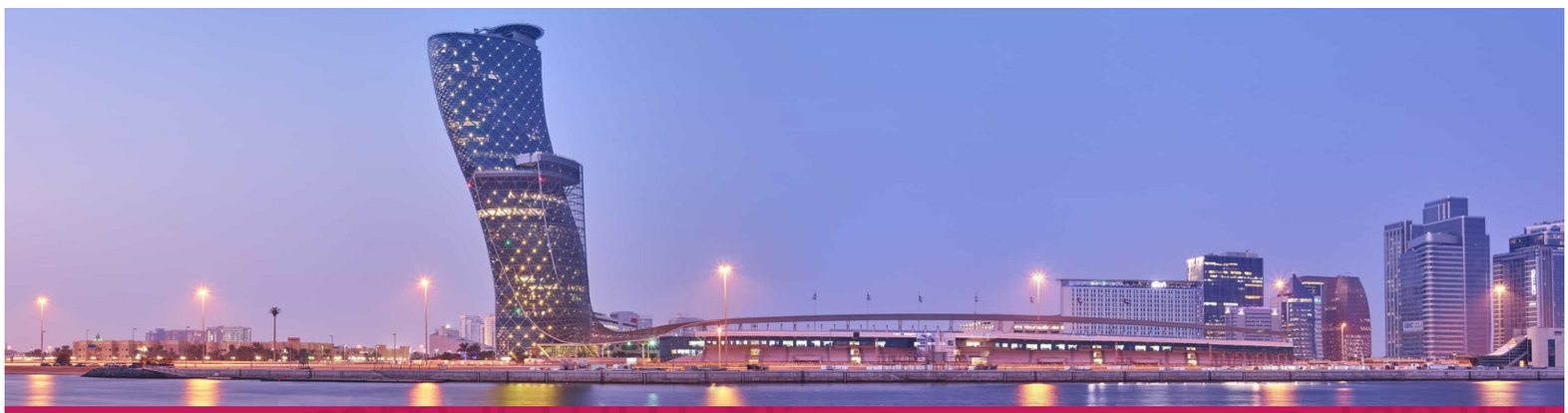

وزارة الدفاع
MINISTRY OF DEFENCE

46th ICMM World Congress of Military Medicine

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INTERNATIONAL COMMITTEE OF MILITARY MEDICINE
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La connaissance par-delà les frontières

Knowledge beyond borders



Notre héritage

La Première Guerre mondiale fut un désastre inqualifiable pour les populations et les forces armées. Les personnels de santé, civils et militaires, de toutes les disciplines de la médecine, alliés ou ennemis, durent déployer des efforts considérables pour tenter de sauver un maximum de blessés et malades, avec les connaissances de l'époque, souvent sommaires face à des lésions et des affections dont personne n'avait jamais entendu parler.

Tous ont oeuvré pour le bien de leurs patients, avec les piètres moyens et savoirs dont ils disposaient, afin de faire face à ces pathologies dévastatrices.



Médecin général-major
Jules VONCKEN



(Navy Captain)
William S. BAINBRIDGE

Naissance

En 1921, le Médecin Commandant **Jules Voncken** et le Navy Captain **William S. Bainbridge**, MD qui s'étaient croisés dans les plaines de l'Yser, mettent sur pied un forum neutre, sous la forme d'une organisation internationale des services médicaux des différentes forces armées.

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INTERNATIONAL COMMITTEE OF MILITARY MEDICINE
COMITÉ INTERNATIONAL DE MÉDECINE MILITAIRE

Qui sommes-nous?

Le Comité International de Médecine Militaire est une organisation intergouvernementale composée des chefs des services médicaux militaires des forces armées des pays membres. Comprenant huit pays membres en 1921, le Comité en compte aujourd'hui près de 121.

La Connaissance par-delà les Frontières...

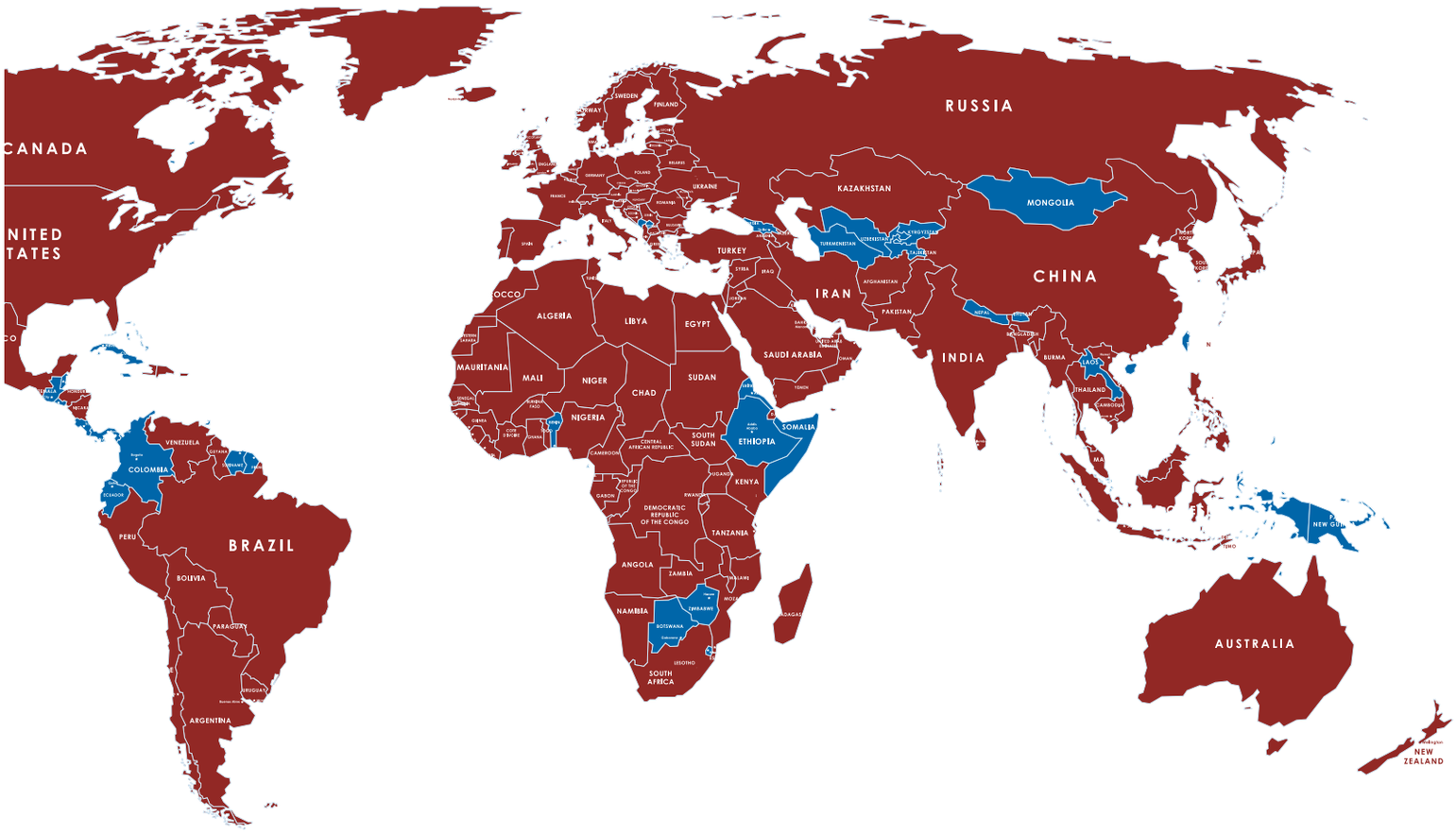
Fort de sa Vision, de sa Mission et de ses Valeurs, le Comité International de Médecine Militaire promeut les échanges de connaissances et d'expériences multidisciplinaires en médecine militaire hors de toute considération d'appartenance politique, religieuse ou philosophique.

Les fondamentaux...

Le Comité International de Médecine Militaire organise des activités scientifiques qui mettent en avant le Droit International Humanitaire et le Règlement Sanitaire International (2005).

Appliquant les principes d'une « diplomatie médicale militaire », le CIMM encourage les contacts internationaux entre les Services Médicaux du monde entier.





Vision

Etre l'organisation de référence en médecine militaire, engagée pour la diffusion des connaissances par-delà des frontières géographiques et idéologiques.

Mission

Améliorer l'échange mutuel des futures orientations, des connaissances scientifiques actuelles et les expériences du passé au sein de la communauté médicale militaire et renforcer la coopération entre la médecine militaire et les organisations internationales traitant de la Santé.

Valeurs

Les Valeurs qui nous guident sont l'indépendance, la neutralité, l'impartialité, l'universalité, la fiabilité, la qualité et la transparence. Nos activités et prises de position sont toujours guidées par les principes moraux.

Magazine

Le CIMM favorise le partage d'expériences de terrain à travers la Revue Internationale des Services de Santé des Forces Armées.

Cette publication, destinée au personnel des services de santé militaire, est disponible gratuitement en ligne et peut également être envoyée par courrier sur simple demande.

Le CIMM incite ainsi tous les personnels de santé du secteur à soumettre leurs articles. ›



Our organisation



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ICMM Chair
ICMM Vice Chairs

General Secretariat
Secretary General
Deputy Secretary General

Executive Office

Scientific Council
Chair
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Technical Commissions

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Regional Working Group Pan American

Regional Working Group Maghreb

Regional Working Group Pan Arabic

Regional Working Group Pan Europe

National Delegates of Member States

Our partners

AMSUS The Society of Federal Health Professionals

CISM

fip ADVANCING PHARMACY WORLDWIDE

COMITÉ INTERNATIONAL GENÈVE CICR

World Health Organization

WVA

WMA WORLD MEDICAL ASSOCIATION

Organisation mondiale de la santé animale
Fondée en tant qu'OIE



Our heritage

The First World War was an unspeakable disaster for the population and the armed forces. Civilian and military medical personnel from all medical disciplines, both allied and enemy, had to make considerable efforts to try and save as many wounded and sick as possible, using the knowledge available at the time, which was often sketchy when faced with injuries and conditions that no-one had ever heard of. They all worked for the good of their patients, with the limited resources and knowledge at their disposal, to deal with these devastating diseases.

Founded ...

In 1921, Commander Jules VONCKEN, MD and Navy Captain William S. BAINBRIDGE, MD, who had met on the plains of the Yser, set up a neutral forum in the form of an international organisation of the medical services of the various armed forces.

Who are we?

The International Committee of Military Medicine is an intergovernmental organisation composed of the Chiefs of Military Medical Services of the armed forces of the member countries. From eight member countries in 1921, the ICMM now has almost 120 members.

Knowledge beyond borders...

On the strength of its Vision, Mission, and Values, the International Committee of Military Medicine promotes the exchange of knowledge and multidisciplinary experience in military medicine, regardless of political, religious, or philosophical affiliation.

The fundamental principles...

The International Committee of Military Medicine organizes scientific activities in the form of congresses, courses and workshops, and publishes a journal highlighting all the healthrelated professions of Military Medicine, International Humanitarian Law and the International Health Regulations (2005).

Applying the principles of "military medical diplomacy", the ICMM encourages international contact between Military Medical Services worldwide.

Vision

To be the world's leading organization in military medicine, committed to sharing knowledge beyond geographical and ideological borders.

Mission

To enhance the mutual exchange of past experiences, current scientific knowledge and future orientations among military medical services and to foster cooperation between military medicine and international health organizations.

Values

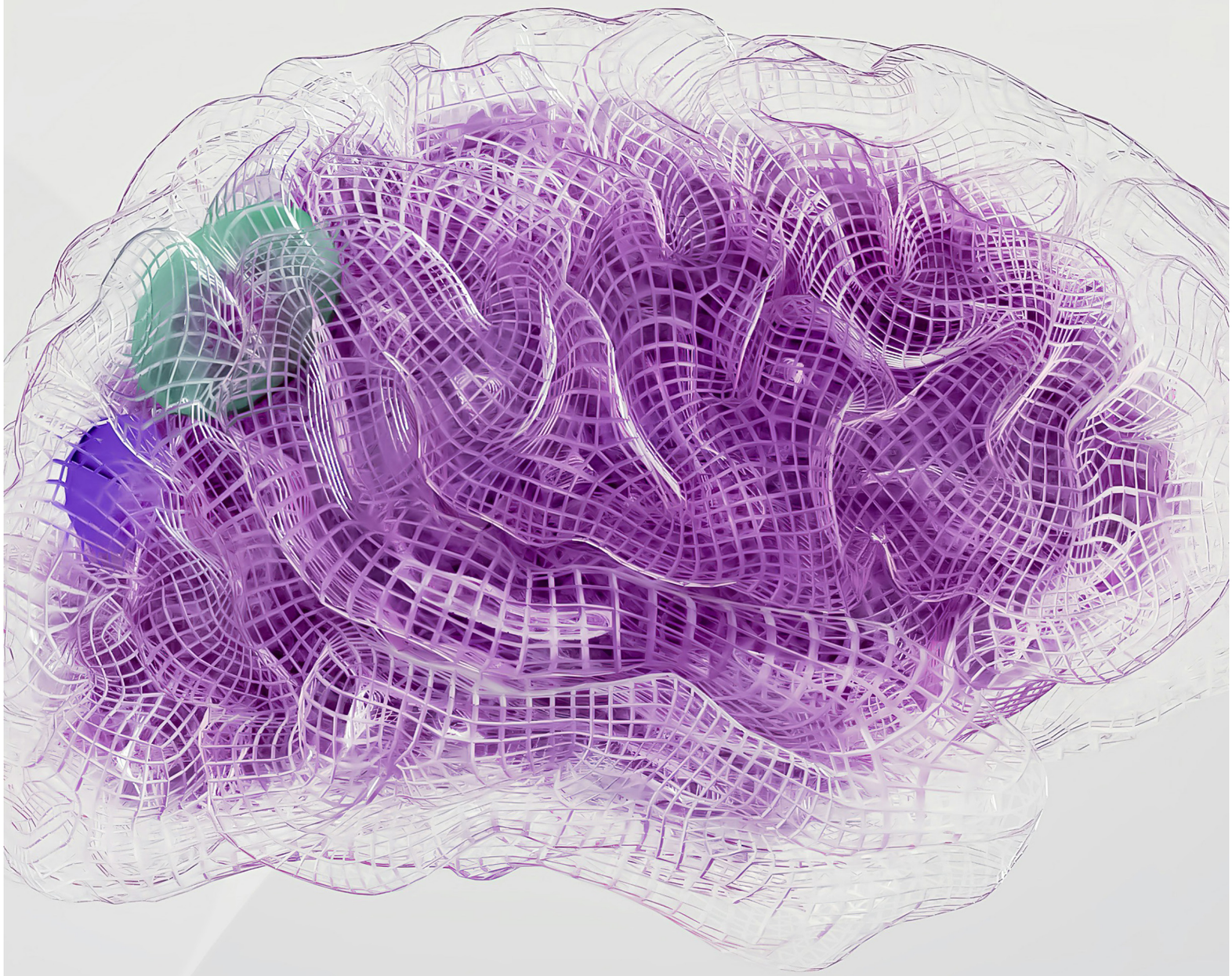
Independence – Neutrality – Impartiality – Universality – Reliability – Quality Transparency always driven by moral principles

Magazine

The ICMM promotes the sharing of field experiences through the International Review of the Armed Forces Medical Services. This publication, intended for military medical service personnel, is available free of charge online and can also be sent by mail upon simple request.

Visualization analysis of research frontiers in medical products for the emergency care of military personnel

MIAN ZU[1], WENBING MA[1], RONGLING YIN[1], WEI LIU[1], LEI WANG[1] - CHINA



[1]Academy of Military Medical Sciences, China

Analyse par visualisation des frontières de la recherche sur les produits médicaux pour les soins d'urgence du personnel militaire

Abstract

Introduction : Medical products for the emergency care of military personnel are pharmaceuticals or vaccines designed to address combat-related injuries and diseases induced by military-specific environments. However, the absence of a systematic overview of global research frontiers in this domain substantially restricts interdisciplinary innovation.

Materials and methods : Utilizing 1,026 publications (2015–2025) from the Web of Science Core Collection, this study mapped research frontiers through a scientometric analysis. We employed hybrid methods—VOSviewer for co-occurrence mapping and BERTopic for topic modeling—and prioritized key frontiers based on citations per year (CPT).

Results: The U.S., U.K., Germany, Italy, India, China, and Czechia formed a collaborative network in military pharmaceutical research. The U.S. held a dominant position in publications, with the DoD and U.S. Army Institute of Surgical Research (Schauer SG's work on trauma pain and resuscitation) as key contributors. Thematic clustering identified seven major research themes. Key research frontiers comprised eight domains: safety and immunogenicity assessment of vaccines against biological agents, TXA in trauma hemorrhage, psychedelics for PTSD therapy, and five additional priority areas.

Conclusion: Through data visualization approaches, this work identifies the evolving research frontiers in military medical therapeutics, enabling comprehensive mapping of the field's progress. The results provide scientific and technological intelligence support for next-generation military drug innovation.

Key Words: visualization, research frontiers, medical products, military

Résumé

Introduction : Les produits médicaux destinés aux soins d'urgence du personnel militaire sont des médicaments ou des vaccins conçus pour traiter les blessures liées au combat et les pathologies induites par les environnements militaires spécifiques. Cependant, l'absence d'une vision systématique des fronts de recherche mondiaux dans ce domaine limite considérablement l'innovation interdisciplinaire.

Matériels et méthodes : À partir de 1026 publications (2015–2025) issues du Web of Science Core Collection, cette étude a cartographié les fronts de recherche grâce à une analyse scientométrique. Nous avons employé des méthodes hybrides — VOSviewer pour la cartographie de co-occurrence et BERTopic pour la modélisation thématique — et avons priorisé les fronts clés en fonction du nombre de citations par an (CPT).

Résultats : Les États-Unis, le Royaume-Uni, l'Allemagne, l'Italie, l'Inde, la Chine et la République tchèque ont formé un réseau de collaboration en recherche pharmaceutique militaire. Les États-Unis ont occupé une position dominante en termes de publications, avec le DoD et l'U.S. Army Institute of Surgical Research (notamment les travaux de Schauer SG sur la douleur traumatique et la réanimation) comme contributeurs majeurs. Le clustering thématique a identifié sept grands axes de recherche. Les fronts de recherche clés comprennent huit domaines: l'évaluation de l'innocuité et de l'immunogénicité des vaccins contre les agents biologiques, l'acide tranexamique (TXA) dans l'hémorragie traumatique, les psychédéliques pour la thérapie du stress post-traumatique (TSPT), ainsi que cinq autres domaines prioritaires.

Conclusion : Grâce à des approches de visualisation de données, ce travail identifie l'évolution des fronts de recherche en thérapeutique médicale militaire, permettant une cartographie complète des progrès dans ce domaine. Les résultats fournissent un soutien en intelligence scientifique et technologique pour l'innovation de nouvelle génération en matière de médicaments à usage militaire.

Mots-clés : visualisation, fronts de recherche, produits médicaux, domaine militaire

Background

Medical products for the emergency care of military personnel (MPMs), also known as combat drugs, include blood products such as freeze-dried plasma, preventive vaccines, and therapeutic medications, et al. They play a crucial role in diagnosing, treating, and preventing severe or life-threatening diseases faced by military personnel.

During World War II, the German army extensively used psychostimulant drug Benzedrine and Pervitin to promote wakefulness, elevate mood and improve field performance *(1)*. In the Afghanistan and Iraq wars, the U.S. military widely employed oral transmucosal fentanyl citrate formulations, which provide rapid analgesic effects *(2)*. However, MPMs still face challenges such as severe side effects, poor controllability, and uncertain efficacy. There is an urgent need to drive the R&D of MPMs through scientific and technological innovation.

Tracking research frontiers in the field of science and technology is of great significance for promoting innovation. Technologies such as natural language processing (NLP), text topic recognition, and complex network analysis have been widely applied in identifying research frontiers *(3)*, significantly improving efficiency and inspiring innovative ideas. This paper intends to utilize topic clustering tools such as VOSviewer and BERTopic to identify research themes in the field of MPMs and select research frontiers based on these themes.

Methods

2.1 Data Source Acquisition and Processing

This study utilizes literature from the Web of Science Core Collection as the data source, covering databases such as Science Citation Index Expanded (SCI-EXPANDED) (1993–present). The search strategy covers various keywords, including but not limited to CBRN injuries, combat trauma and emergency treatment, pathogenic factors, symptoms, drugs, natural products, vaccines, and antibodies associated with battlefield.

2.2 Field Overview Statistics

A bibliometric analysis was conducted on 1,026 scientific papers related to military-specific drugs published in the Web of Science Core Collection over the past decade. The study examined annual publication trends, leading research countries, institutions, and authors, along with a collaboration network analysis to elucidate the developmental landscape of this field.

2.3 Keyword Co–occurrence and Clustering Analysis Based on VOSviewer

VOSviewer was employed to perform document co-citation clustering for identifying research themes. The software utilizes the Smart Local Moving Algorithm based on modularity maximization to conduct co-occurrence analysis of keywords, topics, and other bibliographic elements, with the optimization function:

$$H(c)=\sum_{_}(s_{ij}-\gamma)\ \ \delta(c_{i,j})$$

with s_{ij}: normalized node linkage strength; γ: clustering resolution (γ=1 by default).

2.4 Topic Modeling Based on BERTopic

BERTopic is a topic modeling technique that leverages transformers and c-TF-IDF to extract and cluster topics from textual data. The methodology involves four key steps: *(1)* Embedding Generation, where text is transformed into dense vector representations using embedding models such as sentence transformer; *(2)* Dimensionality Reduction, typically performed via algorithms such as UMAP (Uniform Manifold Approximation and Projection) to reduce computational complexity; *(3)* Clustering, which groups semantically similar embeddings using HDBSCAN (Hierarchical Density-Based Spatial Clustering of Applications with Noise); and *(4)* Topic Representation, where key terms are extracted to characterize each cluster as an interpretable topic. This approach enhances topic coherence and semantic relevance compared to traditional probabilistic topic models.

2.4.1 Calculation of Word Importance Scores per Topic Using the c–TF–IDF Formula

$$\text{c-TF-IDF}(t,c)=\text{TF}(t,c)\times\text{ICF}(t)$$

TF(t,c) denotes the frequency of term t in topic c. ICF(t) (Inverse Class Frequency) is computed as log(1 + N/DF(t)), where: N represents the total number of topics, DF(t) indicates the frequency of term t across all topics.

2.4.2 Optimization of Topic Keyword Selection Based on Maximal Marginal Relevance (MMR) Formula

MMR Score=λ·Relevance(w)-(1-λ),w′ ∈ SmaxDiversity(w,w′)
Where S = currently selected keywords, w = candidate term, w′ = already selected term, λ (lambda) is a weighting parameter ∈ (0,1)

2.5 Identification of Key Research Frontiers

Based on the results of topic clustering and manual judgment, further screening was conducted to identify core papers closely related to each key research frontier. The citation per year per paper (CPT) was used as the selection criterion for key research frontiers. The CPT is calculated by dividing the total number of citations (C) of the core papers by the number of core papers (P), and then dividing by the number of years (T) during which the citing papers were published. T during which the citing papers were published is defined as the difference between the publication years of the latest citing papers and the earliest citing ones.

$$CPT = \frac{\text{(Total Citations (C)}}{\text{(Number of Core Papers (P)} \times \text{Citation Time Window (T)}}$$

Where $T = \text{Publication Year}_{\text{latest citing paper}} - \text{Publication Year}_{\text{earliest citing paper}}$

As a normalized metric of annual citation influence, CPT quantitatively reflects research front dynamics - higher values denote either trending topics or field-defining work, enabling systematic identification of evolving and breakthrough areas.

Results

3.1 Domain Overview

3.1.1 Core Scholars

The most prolific author *(Tab. 1)*, Schauer SG, is affiliated with the U.S. Army Institute of Surgical Research. He has conducted extensive work in multicenter epidemiological studies and medical treatment of major combat trauma, including acidosis, hypocalcemia *(4)*, and airway obstruction *(5)*. His research has evaluated the safety of tromethamine (THAM) for acidosis *(6)* in military personnel in combat scenarios *(7)*, the efficacy of tranexamic acid (TXA) for hemorrhage in combat trauma, and the effectiveness of low-dose ketamine for severe pain *(8)*, among other topics.

The second most prolific author, April MD, is from the Uniformed Services University of the Health Sciences. His research primarily focuses on emergency airway management and shock treatment *(9)*. He has assessed the pain-relieving effects of topical ethyl chloride *(10)*, the rapid relief of seizures with intravenous benzodiazepines *(11)*, the efficacy of nonsteroidal anti-inflammatory drugs (NSAIDs) for biliary colic pain *(12)*, and the improvement of septic shock with glucocorticoids *(13)*.

Authors from other countries include Worek F from the Bundeswehr Institute of Pharmacology and Toxicology in Germany, who has conducted a series of studies on the mechanisms, biomarkers, and treatment of organophosphate poisoning. His work specifically examines the reactivation activity of oximes on acetylcholinesterase *(14)* and the development of monosubstituted sulfonatocalix *(4)* arene as a rapid small-molecule antidote for V-type nerve agents *(15)*. Glassberg E, from Bar-Ilan University in Israel, primarily researches battlefield blood supply, low-titer group O whole-blood resuscitation *(16)*, and the prehospital application of freeze-dried plasma *(17)*.

3.1.2 High–Output Research Institutions

The United States Department of Defense (DoD), as the leading institution in the publication of research on military-specific pharmaceuticals, has conducted extensive studies in this field (Tab. 2). Utilizing the zebrafish model, they screened and identified five compounds with potential therapeutic activity against sepsis: Ketanserin, Tegaserod, Brexpiprazole, Sunitinib, and Ziprasidone (18). Additionally, the DoD has investigated the therapeutic effects of ketamine on traumatic brain injury (TBI) and post-traumatic stress disorder (PTSD) in patients with combat injuries sustained pre-hospital. Their findings suggest that ketamine could serve as a primary analgesic ›

TAB. 1: The top 5 most published scholars in the field of MPMs

Rank	Authors	Record Count	Country	Affiliation
1	Schauer SG	17	USA	US Army, Inst Surg Res
2	April MD	12	USA	Uniformed Serv Univ Hlth Sci
3	Modjarrad K	10	USA	Walter Reed Army Inst Res
3	Worek F	10	Germany	Bundeswehr Inst Pharmacol & Toxicol
4	Chen WH	9	USA	Univ Maryland, Sch Med
4	Currier JR	9	USA	US Mil HIV Res Program
4	Michael NL	9	USA	Walter Reed Army Inst Res
5	Glassberg E	8	Israel	Bar-Ilan University
5	Gromowski GD	8	USA	NIAID, Infect Dis Lab, NIH
5	Kuca K	8	Czech Republic	Univ Hradec Kralove
5	Matyas GR	8	USA	Walter Reed Army Inst Res
5	Tribble DR	8	USA	Uniformed Serv Univ Hlth Sci

TAB. 2 : The top 5 most published affiliations in the field of MPMs

Rank	Affiliation	Record count	Country
1	United States Department of Defense	116	USA
2	Uniformed Services University of the Health Sciences USA	84	USA
3	Us Department of Veterans Affairs	80	USA
4	Veterans Health Administration VHA	78	USA
5	United States Army	77	USA
6	Henry M Jackson Foundation for the Advancement of Military Medicine inc	42	USA
7	University of California System	41	USA
8	San Antonio Military Medical Center	40	USA
9	Walter Reed Army Institute of Research Wrair	37	USA
10	Walter Reed National Military Medical Center	33	USA

for combat-related injuries. Furthermore, they evaluated the therapeutic potential of a 5-ApoE mimetic peptide, CN-105, for the treatment of TBI *(19)*.

3.1.3 Country Co–authorship Network

In the field of MPMs R&D, the United States, as the country with the highest number of publications, has established extensive and close collaborations with Israel, France, Germany, the United Kingdom, Canada, India, China, Czech Republic, and Australia *(Fig.1)*. These collaborations encompass a wide range of areas, including the use of tranexamic acid for the treatment of casualties in the Iraq-Afghanistan battlefield and the development of novel pharmacological treatments for military-related post-traumatic stress disorder (PTSD). Further-

FIG.1 Global Collaboration Network Among Countries in in the field of MPMs

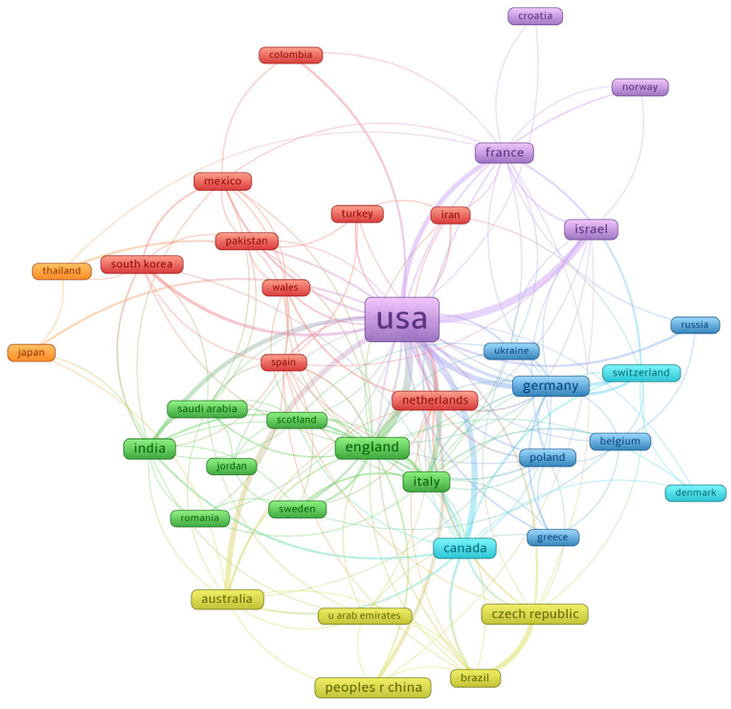
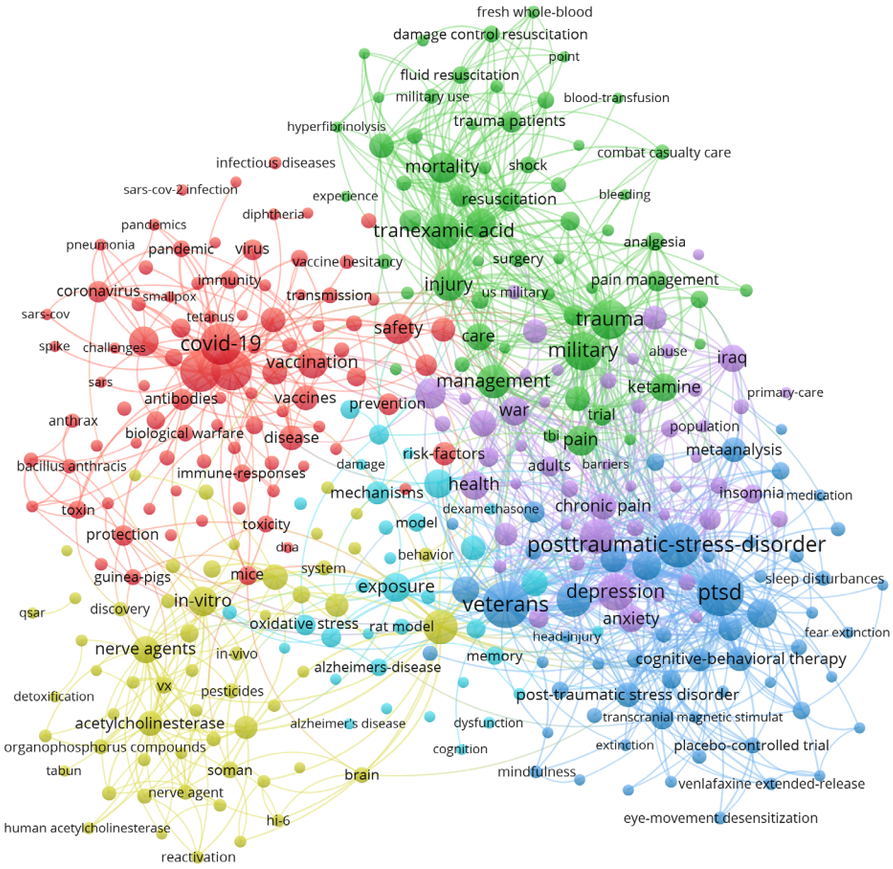


FIG.2 Keyword Co-occurrence and Clustering Network



more, the Czech Republic and Brazil have engaged in a series of collaborative efforts focusing on the efficacy and safety evaluation of new acetylcholinesterase reactivators, as well as potential therapeutic targets such as dihydrofolate reductase for Q fever pathogens and Yersinia pestis *(20)*.

3.2 Major Research Topics

3.2.1 Keyword Co-occurrence and Clustering Analysis Using VOSviewer

Analysis revealed six research topics: 1. Antibody and Vaccine Development for Biological Agents; 2. Analgesics and Pain Management for Combat Injuries; 3. Pharmacological and Cognitive Behavioral Therapies for PTSD, Depression, and Anxiety; 4. Therapeutic Agents for Chemical Warfare Agent Poisoning; 5. Risk Factors and Pathological Mechanisms of Traumatic Brain Injury; 6. Epidemiology and Rehabilitation of Insomnia and Chronic Pain *(Fig. 2)*.

3.2.2 Topic Modeling and Keyword Clustering Based on BERTopic

Eight research topics were identified: 1. Military personnel COVID-19 vaccination; 2. PTSD symptomatology and treatment in veterans; 3. Organophosphate-induced brain injury and treatment; 4. Traumatic hemorrhagic shock and prehospital resuscitation; 5. Comorbid sleep disorders and PTSD in active/retired military; 6. TBI and cognitive rehabilitation in veterans;7. Anxiety/depression management and mental healthcare; 8. Cyclosporine formulations for hemostatic applications *(Fig.3)*.

3.3 Key research frontiers

The integration of VOSviewer and BERTopic clustering results, followed by expert review and CPT-based ranking, offers a robust framework for identifying and prioritizing key research frontiers. This methodological approach ensures a balanced consideration of both quantitative and qualitative factors, thereby enhancing the reliability and relevance of the identified research priorities. Based on the expert review, eight key research frontiers were meticulously selected from the consolidated clusters. These frontiers represent the most promising and impactful areas of current scientific inquiry within the domain under investigation. The following only outlines the first two research frontiers *(Tab.3)*.

3.3.1 Psychedelic–assisted therapy for PTSD

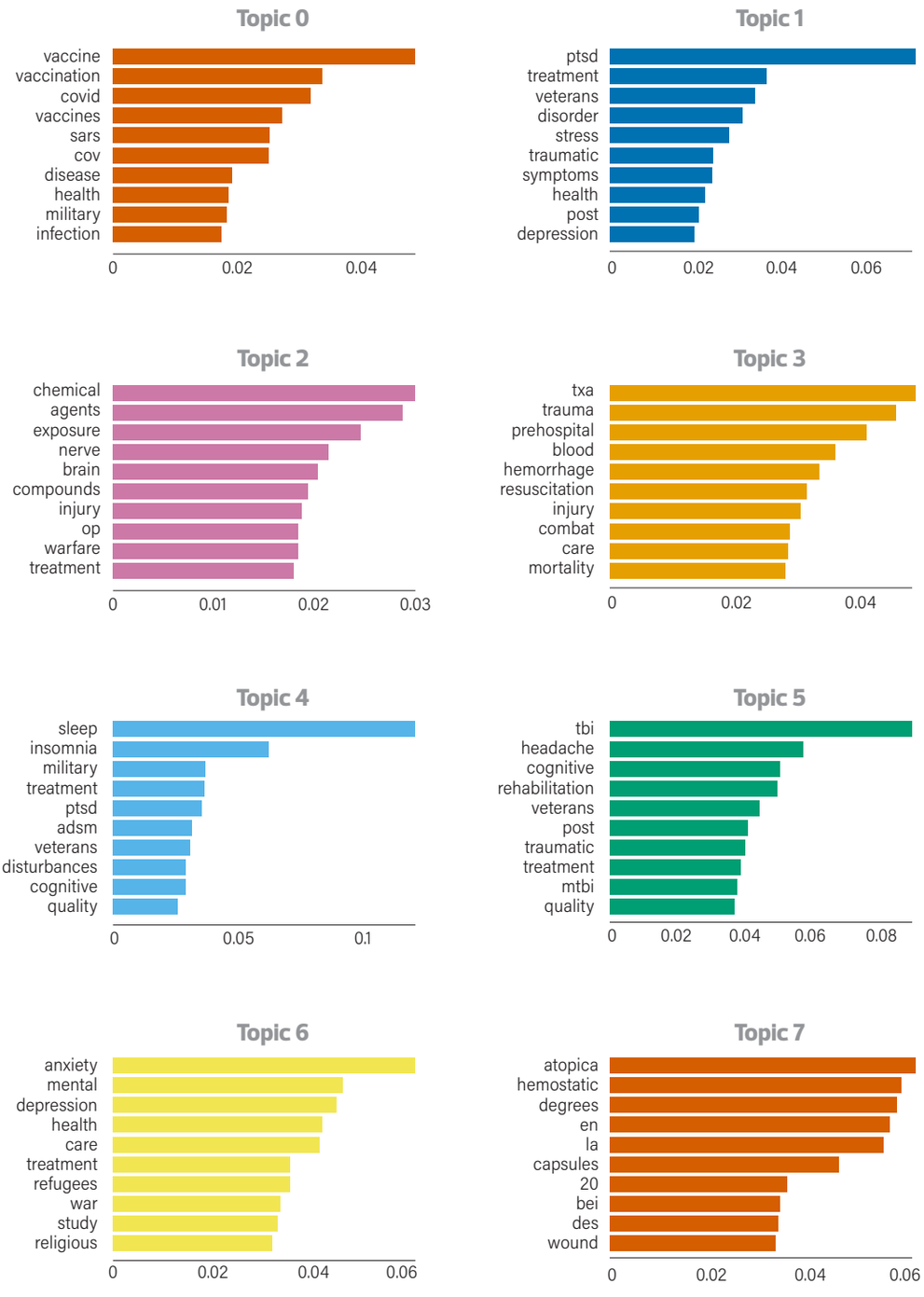
Post-Traumatic Stress Disorder (PTSD) is a complex psychiatric ›

condition characterized primarily by anxiety and depression, which develops following exposure to catastrophic events (21). It is prevalent among veterans with deployment experience, and prolonged combat deployments exacerbate the mental health crises among both active-duty and retired military personnel *(22)*. PTSD and other psychological disorders contribute to an increasing trend in suicide rates among military personnel, with negative impacts that can even surpass the direct consequences of war itself.

Cognitive Behavioral Therapy (CBT) is currently the most supported first-line psychological intervention for PTSD. Pharmacological treatments remain as second-line therapies. The U.S. Food and Drug Administration (FDA) has approved paroxetine and sertraline for the treatment of PTSD. Both of these medications are classified as Selective Serotonin Reuptake Inhibitors (SSRIs).

The use of hallucinogens and other substances as adjunctive treatments for PTSD is supported by 14 core papers. The

FIG.3 Topic Word Cluster Diagram Produced by BERTopic



TAB.3 : The top 8 key research frontiers in MPMs by expert review and CPT-based ranking

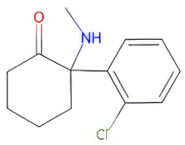
SN	Key research frontiers	Number of Core Papers (P)	Total Citations (C)	Citation Time Window (T)	Citations per Paper per Year(CPT)
1	Psychedelic-assisted therapy for PTSD	13	404	10 (2016-2025)	3.11
2	Medical applications of cannabinoid compounds	8	220	10 (2016-2025)	2.75
3	TXA in combat trauma hemorrhage control	27	733	10 (2016-2025)	2.71
4	Freeze-dried plasma for battlefield resuscitation	8	219	11 (2015-2015)	2.49
5	Safety and immunogenicity evaluation of vaccines against biological warfare agents including smallpox	25	381	10 (2016-2025)	1.52
6	Design and pharmacodynamic evaluation of novel cholinesterase reactivators	25	329	10 (2016-2025)	1.32
7	Bioscavengers for chemical warfare agents: design and engineering of humanized acetylcholinesterase and butyrylcholinesterase	5	66	10 (2016-2025)	1.32
8	Efficacy studies of vaccinations including COVID-19 in armed forces personnel	16	73	8 (2018-2025)	0.57

TAB.4: Characteristics of Text Mining Using BERTopic and VOSviewer

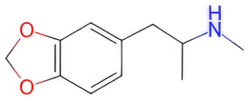
Evaluative dimension	BERTopic	VOSviewer
Technical Principles - Underlying Models	Based on the embedding representation of the BERT pre-trained model, with the clustering algorithm of UMAP combined with HDBSCAN.	Based on co-occurrence networks, and the clustering algorithm employs the Smart Local Moving Algorithm.
Technical Principles - Semantic Understanding Capability	Strong, leveraging deep learning to capture contextual semantics.	Weak, relying on word frequency or co-occurrence statistics, thereby neglecting contextual information.
Technical Principles - Visualization Methods	Topic word clouds, hierarchical topic maps, etc.	Node-edge relationship graphs
Application Scenario 1 - Analysis of the Evolution of Literature Topics	Supports application through time series modeling.	Supports application but requires additional tools for assistance.
Application Scenario 2 - Analysis of Key-word Co-occurrence Networks	Does not support this application as it is not a core function.	Supports application as it is a core function.
Application Scenario 3 - Short Text Clustering	Supports application, with BERT demon-strating strong capability in processing short texts.	Does not support application due to poor performance caused by sparsity.

FIG.4 Partial Small Molecule Entities Obtained through Text Mining

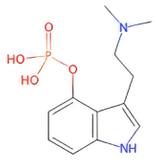
PTSD



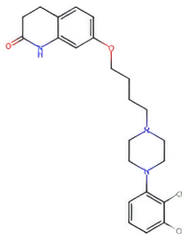
Ketamine



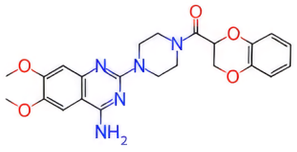
MDMA



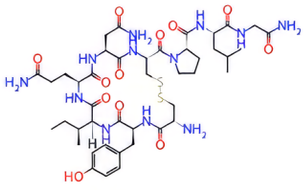
Psilocybin



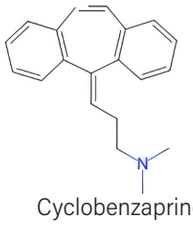
Arripiprazole



Doxazosin

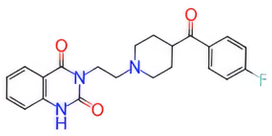


Oxytocin

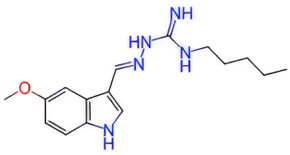


Cyclobenzaprine

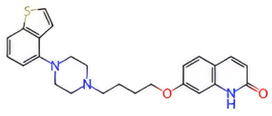
Scepsis



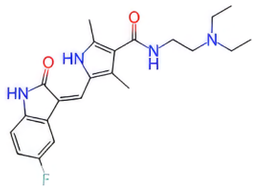
Ketanserin



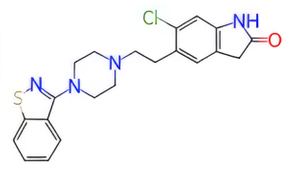
Tegaserod



Brexpiprazole

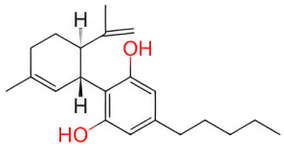


Sunitinib

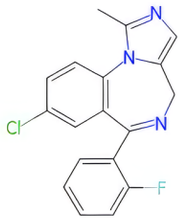


Ziprasidone

Seizures

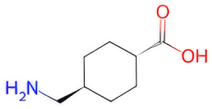


Cannabidiol



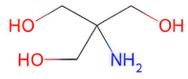
Midazolam

Hemorrhage



tranexamic acid

Acidosis



tris(hydroxymethyl)aminomethane

relevant hallucinogens primarily include 3,4-Methylenedioxymethamphetamine (MDMA), ketamine, and psilocybin. Currently, MDMA is the most advanced in terms of development, having completed Phase III clinical trials. In early 2024, the U.S. Food and Drug Administration (FDA) accepted a New Drug Application (NDA) submitted by Lykos Therapeutics for 3,4-Methylenedioxymethamphetamine (MDMA) and granted it priority review status. This drug, when combined with psychological interventions, is intended as an adjunctive treatment for PTSD patients.

A notable study published in *The Lancet Psychiatry* in 2018 reported the results of a Phase II clinical trial on the adjunctive treatment of PTSD with MDMA *(23)*. This paper has been cited 210 times. Given the prevalence of PTSD among military personnel and first responders, yet the significant number of patients who do not receive effective treatment, the study focused on service members aged 18 and older. It evaluated the efficacy and safety of MDMA-assisted psychotherapy in treating chronic PTSD in this population. The study found that active doses (75mg and 125mg) of MDMA, combined with psychotherapy, were effective and well-tolerated in reducing PTSD symptoms in veterans and first responders.

Additionally, other emerging drugs for the treatment of PTSD include aripiprazole, doxazosin, oxytocin, and cyclobenzaprine. These drugs, which target new mechanisms, hold promise as novel solutions for the treatment of PTSD. The development of these new treatments could potentially offer significant improvements in the management of PTSD, addressing the unmet needs of affected individuals.

3.3.2 Medical applications of cannabinoid compounds

Cannabidiol (CBD) is the primary non-psychoactive component of cannabis, distinct from tetrahydrocannabinol (THC), the addictive component of cannabis. Extensive research has demonstrated that CBD has various pharmacological effects on the nervous system, including significant anti-epileptic, anti-seizure, anti-anxiety, antibacterial, and anti-inflammatory properties with fewer side effects *(24)*. In December 2020, the United Nations Commission on Narcotic Drugs officially removed cannabis from Schedule IV of the 1961 Single Convention on Narcotic Drugs, lowering the regulatory classification of cannabis and cannabis-related substances. This was done to promote medical research on cannabis. Academic research evidence supports the rapid growth of the medical cannabis market. According to Cowen Group's forecast, by 2025, the value of the CBD industry in the United States alone will reach $16 billion. On June 25, 2018, the U.S. FDA approved Epidyolex, a CBD-containing substance developed by British GM Pharma, which acts on targets in the brain involved in seizures, as an orphan drug for the adjunctive treatment of epilepsy associated with TSC, Lennox-Gastaut syndrome (LGS), and Dravet syndrome (DS). However, cannabis has hallucinogenic and addictive risks, so countries' laws strictly regulate it in three categories: drug cannabis, medical cannabis, and industrial cannabis. Among them, medical cannabis has a THC content of 0.3%-0.5%, offering broad medical application potential.

The research frontier "Medical applications of cannabinoid compounds" comprises 9 core papers, primarily focusing on the anticonvulsant efficacy of cannabidiol in epilepsy animal models, its mechanisms of action, pharmacokinetics, and drug interactions, as well as the therapeutic effects of cannabidiol on veterans with PTSD and its rapid treatment effects on PTSD co-occurring with substance use disorders. Among these, the paper titled "Coadministered cannabidiol and clobazam: Preclinical evidence for both pharmacodynamic and pharmacokinetic interactions," published in the journal Epilepsia in 2019 *(25)*, has the highest citation count, with 88 citations. This study investigated the pharmacokinetic and pharmacodynamic interactions between cannabidiol and clobazam, a first-line drug for epilepsy treatment. It found that cannabidiol can inhibit the activity of clobazam-metabolizing enzymes, increasing the blood concentration of clobazam. The combination of the two drugs can also enhance the activity of inhibitory GABA receptors, resulting in a stronger anticonvulsant effect. Two papers proposed the anticonvulsant mechanisms of cannabidiol through the transient receptor potential vanilloid 1 (TRPV1) and PI3Kγ pathways.

Discussion

4.1 The strengths and weaknesses of BERTopic and VOSviewer in text mining

In terms of technical principles, BERTopic employs an embedding representation based on pre-trained language models as its underlying model. This allows it to leverage deep learning to capture contextual semantics, thereby exhibiting strong semantic understanding capabilities. BERTopic is capable of generating visualizations such as topic word clouds and hierarchical topic maps. On the other hand, VOSviewer's underlying model is based on co-occurrence networks or citation networks. It relies on word frequency or co-occurrence statistical results, thereby neglecting contextual semantics. VOSviewer can generate relationship graphs based on node-edge relationships.

In terms of application scenarios, both BERTopic and VOSviewer can be used for the analysis of the evolution of academic literature topics. BERTopic supports time series analysis, enabling the tracking of topic evolution and dynamic topic modeling. However, BERTopic does not support keyword co-occurrence

› network analysis, whereas VOSviewer does. BERTopic excels in processing short texts and supports clustering based on short texts such as titles. In contrast, VOSviewer's ability to cluster short texts is poor due to the sparsity of co-occurrence (Tab.4).

This study compares the analysis of scientific literature using these two tools, focusing on the generation of clustering of research topics in military-specific drugs. BERTopic generates a greater number of topics than VOSviewer, and the granularity of these topics is finer. For instance, regarding PTSD-related topics, VOSviewer generates topics related to PTSD medications and cognitive therapy. In contrast, BERTopic, by deeply capturing contextual semantics, generates two distinct topics: "PTSD symptomatology and treatment in veterans" and "Comorbid sleep disorders and PTSD in active/retired military."

Seven major research themes were identified through integration of VOSviewer and BERTopic clustering results: *1.* Antibodies and vaccines against biological agents; *2.* Military personnel vaccination programs; *3.* Combat trauma analgesia and hemorrhagic emergency medications; *4.* Therapeutics for war-related psychiatric disorders; *5.* Medical countermeasures for chemical warfare agent poisoning; *6.* TBI and cognitive rehabilitation in veterans; *7.* Epidemiology and rehabilitation of insomnia/chronic Pain.

The findings of this study highlight the strengths and weaknesses of BERTopic and VOSviewer in the context of scientific literature analysis. BERTopic's ability to leverage deep learning for capturing contextual semantics and its support for time series analysis make it a powerful tool for detailed and dynamic topic modeling. However, its lack of support for keyword co-occurrence network analysis is a limitation. VOSviewer, while less effective in short text clustering due to co-occurrence sparsity, offers strong capabilities in keyword co-occurrence network analysis. The choice between these tools should be based on the specific requirements of the analysis task at hand.

4.2 Drug discovery based on text mining

Research has identified several novel classes of small molecule entities that show potential for the treatment of post-traumatic stress disorder (PTSD), sepsis, seizures, hemorrhage, and acidosis (Fig.4). These entities exhibit promising therapeutic properties and may provide new avenues for addressing these complex and challenging medical conditions. Further investigation is warranted to elucidate their mechanisms of action and optimize their efficacy in clinical applications.

Moving forward, we will utilize medical entity naming to extract entities and relationships related to drugs, proteins, genes, symptoms, and more. These extracted entities and their relationships will be used to construct a knowledge graph. This process will involve identifying and categorizing relevant medical terms and concepts, and then mapping the intricate connections between them to create a comprehensive and structured representation of the medical knowledge. The resulting knowledge graph will serve as a powerful tool for various applications, including drug discovery, disease understanding, and personalized medicine. Knowledge graphs can integrate multi-omics data, including genomics, transcriptomics, proteomics, and metabolomics, to provide a holistic view of the biological landscape. By incorporating these diverse data types, researchers can gain a deeper understanding of the molecular mechanisms underlying diseases and the potential targets for drug intervention. This integrative approach facilitates the identification of novel drug-disease connections and supports the development of more targeted therapies. ●

Dr. Mian Zu



Dr. Mian Zu (born February 1987) serves as a researcher at the Academy of Military Medical Sciences, Beijing, China. A graduate of Peking Union Medical College's Institute of Materia Medica where she received his doctoral degree in Pharmacology (2013), her research specialization encompassing the target validation of novel anti-influenza viral drug candidates based on host cell proteins, as well as the discovery and development of innovative therapeutics. Additionally, she joined the Academy of Military Medical Sciences in October 2019, where she currently serves as a civilian associate researcher. She is now dedicated to investigating the evolutionary trajectories of interdisciplinary biotechnology development based on text mining and Natural Language Processing technology, as well as conducting strategic research on biotechnological advancement.

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Military Nursing – Developing Multinational Interoperability

Soins infirmiers militaires – Développer l'interopérabilité multinationale.

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Abstract

This is the second in a series of three related papers around the central topic of interoperable working amongst military medical teams. The first paper set the scene by exploring the nature of interoperability and explaining why it is a strategically important consideration in deployment planning. This paper extends that work, examining considerations of the complexities of military nursing interoperability within multinational medical teams at a more tactical level. It investigates how differences in military healthcare systems, nursing specialties, and training frameworks impact the ability of multinational teams to deliver cohesive and effective patient care in operational environments.

Key factors such as pre-deployment training, multinational familiarisation programmes, and role-specific competencies are discussed in relation to fostering interoperability in deployed nursing teams across ICMM member nations. Challenges such as variances in international nursing curricula, clinical role expectations, and practice standards are identified, with a focus on how these differences can be mitigated through common operational training, shared doctrines, and enhanced communication. Furthermore, we assess the influence of cultural differences, hierarchical structures, and unique national healthcare models on team cohesion and clinical decision-making.

This paper addresses the need for tailored training pathways, including military-specific education and civilian transition processes, to ensure that military nurses are adequately prepared for the demands of deployment. The role of health surveillance systems like EpiNATO-2 is also discussed, emphasising the importance of data sharing and situational awareness to improve health outcomes in deployed forces. The UK's adoption of the Lead Nation Model is highlighted as a successful strategy for overcoming command and logistical challenges in multinational settings. Ultimately, the authors call for a structured, collaborative approach to military nursing education and training to overcome existing barriers to interoperability and ensure the delivery of high-quality care in diverse, multinational operational settings.

Keywords: Military Healthcare, Deployed Healthcare, Interoperability, Co-operation, Military Nursing

Picture: Joint US/UK MEDEVAC training on Op Biloxi

Résumé

Il s'agit du deuxième d'une série de trois articles consacrés au thème central de l'interopérabilité entre les équipes médicales militaires. Le premier article posait le cadre en explorant la nature de l'interopérabilité et en expliquant pourquoi elle constitue un élément stratégique important dans la planification des déploiements. Le présent article prolonge ce travail en examinant les considérations relatives à la complexité de l'interopérabilité des soins infirmiers militaires au sein d'équipes médicales multinationales à un niveau plus tactique. Il examine comment les différences entre les systèmes de santé militaires, les spécialités infirmières et les cadres de formation influent sur la capacité des équipes multinationales à fournir des soins cohérents et efficaces aux patients dans des environnements opérationnels.

Des facteurs clés tels que la formation préalable au déploiement, les programmes de familiarisation multinationaux et les compétences spécifiques à chaque rôle sont abordés en relation avec la promotion de l'interopérabilité au sein des équipes infirmières déployées dans les pays membres de l'ICMM. Les défis tels que les variations dans les programmes d'études infirmières internationaux, les attentes en matière de rôles cliniques et les normes de pratique sont identifiés, en mettant l'accent sur la manière dont ces différences peuvent être atténuées grâce à une formation opérationnelle commune, des doctrines partagées et une communication améliorée. En outre, nous évaluons l'influence des différences culturelles, des structures hiérarchiques et des modèles de soins de santé nationaux uniques sur la cohésion de l'équipe et la prise de décision clinique.

Cet article traite de la nécessité de mettre en place des parcours de formation sur mesure, y compris une formation spécifique à l'armée et des processus de transition vers la vie civile, afin de garantir que les infirmières militaires soient suffisamment préparées aux exigences du déploiement. Le rôle des systèmes de surveillance sanitaire tels que EpiNATO-2 est également abordé, en soulignant l'importance du partage des données et de la connaissance de la situation pour améliorer les résultats sanitaires des forces déployées. L'adoption par le Royaume-Uni du modèle de nation chef de file est mise en avant comme une stratégie efficace pour surmonter les défis en matière de commandement et de logistique dans les contextes multinationaux. Enfin, les auteurs préconisent une approche structurée et collaborative de l'éducation et de la formation en soins infirmiers militaires afin de surmonter les obstacles existants à l'interopérabilité et de garantir la prestation de soins de haute qualité dans des contextes opérationnels diversifiés et multinationaux.

Mots clés: Soins de santé aux militaires, Soins de santé déployés, Interopérabilité, Coopération, Soins infirmiers miltaires

Introduction

The military operating environment is increasingly complex. Diverse operations range from warfighting to supporting humanitarian disasters including civilian / military cooperation activities, such as the global emergency response to Covid-19. Each of these operational activities is associated with varying degrees of medical risk, which need to be planned for and mitigated against *(1)*. The current drive towards interoperability, which is based upon a collaborative approach towards shared strategic, operational, and tactical goals, has become an intrinsic part of medical planning *(2)*. Indeed, NATO views multinational medical capabilities, where alignment of clinical standards and quality processes is a "critical enabler" of operations *(3)*. Ensuring an effective process for the management of sick and injured personnel adds to the credibility of Defence organisations by facilitating an interoperable approach that creates mutual trust between nations. However, the concept of medical interoperability is not the sole domain of large-scale organisations such as NATO and the UN. Medical interoperability captures the interest of wider international military collaborations, such as the International Committee for Military Medicine (ICMM), and non-governmental organisations (NGO) *(4)*. The first paper in this short series *(5)* presented the background and justification for interoperable working and its recognised challenges and benefits. This second paper aims to examine some of the recommendations on how to overcome those challenges to develop models of interoperable practice that enable mission success and capitalise on the benefits highlighted in the first paper *(5)*.

With a long and distinguished history of contributions to military operations, nursing care sits at the heart of deployed medical capability. Indeed, developments and modernisation in such medical capabilities over the last few decades have seen military nurses are increasingly working in joint multinational operational environment. However, reaching consensus on how military nurses across the world practice and deliver their roles is an enduring challenge, and something that requires a closer examination of the principles of interoperability to help overcome. The way nursing is professionally respected, utilised, and exerts its influence on healthcare delivery can be very different between nations *(6)*. The broad ICN definition of nursing *(7)* typifies these differences. The ICN definition identifies the core pillars of autonomous care delivery, health protection and promotion, advocacy for patients, supporting education, and developing policy, However, it offers little specific detail and perhaps compounds the complexities of the role's practical application, particularly in the deployed environment.

Within the deployed setting, military nurses from various nations are expected to work together seamlessly and interoperably as dictated by organisational doctrine or policy (e.g., NATO, UN etc.), political agreement (between coordinating States in a coalition), or operational need. Consequently, there needs to be a more in-depth understanding of the common elements of military nursing and operational practices and any discrepancies between partner nations, including their training and education, professional development, and any specialist clinical capabilities. As an example, this paper will explore the convergence and divergence of military nursing roles between the ICMM member States of the United Kingdom (UK), Australia, Belgium, and Spain. The primary intent is to explore the variance in capability between these nations in the delivery of operational patient care. In so doing, the paper will examine possibilities for maximising opportunity and optimising deployed nursing expertise, and ultimately realising the benefits detailed in the earlier paper *(5)*.

Achieving Interoperability

The evidence discussed thus far presents a range of challenges and issues for the concept of interoperability that are driven by geographical and political context. The development of pragmatic considerations in preparing for deployed medical interoperability is essential for optimising subsequent patient care outcomes. Kirsch et al. identified six key considerations, outlined below, when planning for and developing interoperability *(8)*. Although originally designed for civilian-military collaboration, these themes provide a useful structure that are broadly applicable to a nursing focus with the intent of developing effective interoperability (8). Real world examples of these themes are useful when planning military healthcare, and specifically nursing practice. Kirsch et al.'s six themes are:

1. **Co-ordination, collaboration, and communication.**
2. **Funding and incentives.**
3. **Staffing, capacity, and competencies.**
4. **Clinical, support, and surge capacity.**
5. **Training, education, and exercises.**
6. **Metrics and benchmarking.**

Each of these themes has implications for medical interoperability and C3 (command, control, and coordination) on operational deployment from the three perspectives of interoperability: strategic, tactical / operational, and technological *(2)*. The effects of these themes and interoperability perspectives are observable across a wider medical footprint, such as a field hospital. However, as members of the ICMM Technical Commission for Nurses and Paramedics the authors have primarily used the example of nursing to illustrate the effect at the tactical / operational and technological levels for what



is traditionally the largest professional group in any deployed Medical Treatment Facility (MTF). The authors have considered in depth the formal education pathways of specific contributing nations as well as informal and innovative military training solutions and recommendations.

Co-ordination, Collaboration and Communication

A deployed medical team may be comprised of personnel from many different nations, making effective communication of paramount importance in the context of providing the best standards of patient care. Given the nature of their work, there is no room for misunderstandings within deployed healthcare teams. Establishing clear communication is a vital component of safe patient care. While a lingua franca (a common language) is helpful, commanders must take a careful approach to communication so that teamwork and trust develops throughout the MTF, and optimal functioning is achieved (9). Whilst a lingua franca is useful in coalition operations, there is a need to ensure this approach also encapsulates a common medical language.

Command structure is important in strategic and operational planning for multinational facilities, with the lead nation's senior officer usually placed in overall command. However, despite being outlined in doctrine, conflict might still occur at the tactical interoperability level. For example, in a recent study nursing personnel reported occasions when personnel from other nations refused to obey orders from the lead nation's officers, accepting only those from their own chain of command *(10)*.

These behaviours and attitudes clearly compromise interoperability and create barriers to achieving optimal patient care. Situations like those in the example, highlight why common pre-deployment training is vital and will be discussed below.

The nature of a military organisation naturally lends itself to a linear and strictly hierarchical structure, for reasons of command and control. Different military cultures and hierarchies might give rise to misunderstanding or confusion when two or more nations work together. As an additional confounding factor to nursing interoperability, disparity in rank may result in legitimate professional decisions involving patient care, made by a nurse junior in military rank but professionally advanced, being overruled by officers of senior military rank, even if they are not as professionally qualified. Indeed, Cordell highlighted, "in the US Armed Forces, for example, all serving registered nurses are commissioned officers, whereas in most other nations nurses will be 'enlisted ranks' (i.e., non-commissioned officers (NCO)" *(11)*.

The idea of an officer taking orders from a junior NCO would rightly be considered unpalatable in the wider Service environment because of the strict hierarchy and the need to maintain a distinct chain of command in the warfighting scenario. However, the same should not always be true of the professional nursing environment. This is because specialist nursing experience, such as that of an Advanced Nurse Practitioner, may drive clinical decision-making which transcends the conventional military hierarchy to maximise patient outcomes. The influence of a rigid military hierarchy, including that of non-medical personnel and other nations, applied without understanding this ›

› distinction, could create an environment of limited autonomy in healthcare professionals' decision-making *(12)*. The latter has a high potential to hinder effective interoperability between multinational medical teams and compromise patient outcomes, as well increasing the risk of nurses developing moral distress.

Funding and incentives

Kirsch et al. identified funding as a challenging aspect of interoperability, regardless of whether it was military-military or civilian-military (8). There is a significant cost associated with caring for those injured in conflict, humanitarian, or disaster relief operations, which requires a considerable budget. In 2023, all NATO members' Defence Ministers reaffirmed their countries' commitment to spend 2% of their Gross Domestic Product (GDP)on defence capability *(13)*. In early 2025, the UK committed to increasing military funding to 2.5% of GDP by 2027. This demonstrates the political will of each member State to maintain readiness for collective defence within NATO and represents a source of indirect funding to the organisation. However, NATO only places an obligation on member States for direct contributions when a specific operation e.g., an article 5 collective defence operation is triggered[1]. Although the commitment to spending 2% of GDP exists, not all nations meet this in practice. The variance of spending across NATO member States means that interoperability funding can be problematic, even in a well-established organisation. Pernin et al. argued it is unclear as to whether the benefits of interoperability outweigh the costs *(4)*. Investment in technological and training compatibility are both time consuming and can result in dependence on partners to deliver effect, resulting in operational stove piping where no single contributor can be held to account.

As outlined in detail in the first paper in this series (5), key incentives for developing effective interoperability are to share the resource burden and enhance capabilities through collaboration *(13, 14)*. This will not be explored in any further depth within this paper but is understood to be a driving factor behind the NATO commitment to developing interoperable working and improving patient outcomes across its members *(3)*.

Staffing, capacity, and competencies

Nations deploying in a coalition or other multinational operation often experience a wide variance in the roles that nurses undertake, and the clinical skills and qualifications they possess to enable them. It is important that these differences are recognised prior to deployment. An example is that of the Role 3 hospital in Camp Bastion, Afghanistan, where predominantly UK and US nurses were integrated in departments across the hospital. In the operating theatres, it became apparent that US nurses do not undertake training for the core scrub nurse role that is an acknowledged practice for UK nurses. Instead, the US military employs scrub technicians to perform that role *(15, 16, 17)*. A similar example is highlighted in the care of critically ill patients. Recognising that Australian and UK critical care nurses take a holistic approach to the care of ventilated patients, the US model employs 'respiratory technicians' to perform specific roles such as the operation and maintenance of patient ventilation systems.

Across the European militaries, many of the drivers for the operational role are subsumed within NATO doctrine and its associated collective defence policies and processes. Shared doctrine such as NATO outlining the MTF roles provides clear understanding to contributing nations. Figure 1 shows the Belgian medical services' continuum of care in their Operational Patient Care Pathway (OPCP), which like all NATO nations, is rooted firmly in NATO doctrine.



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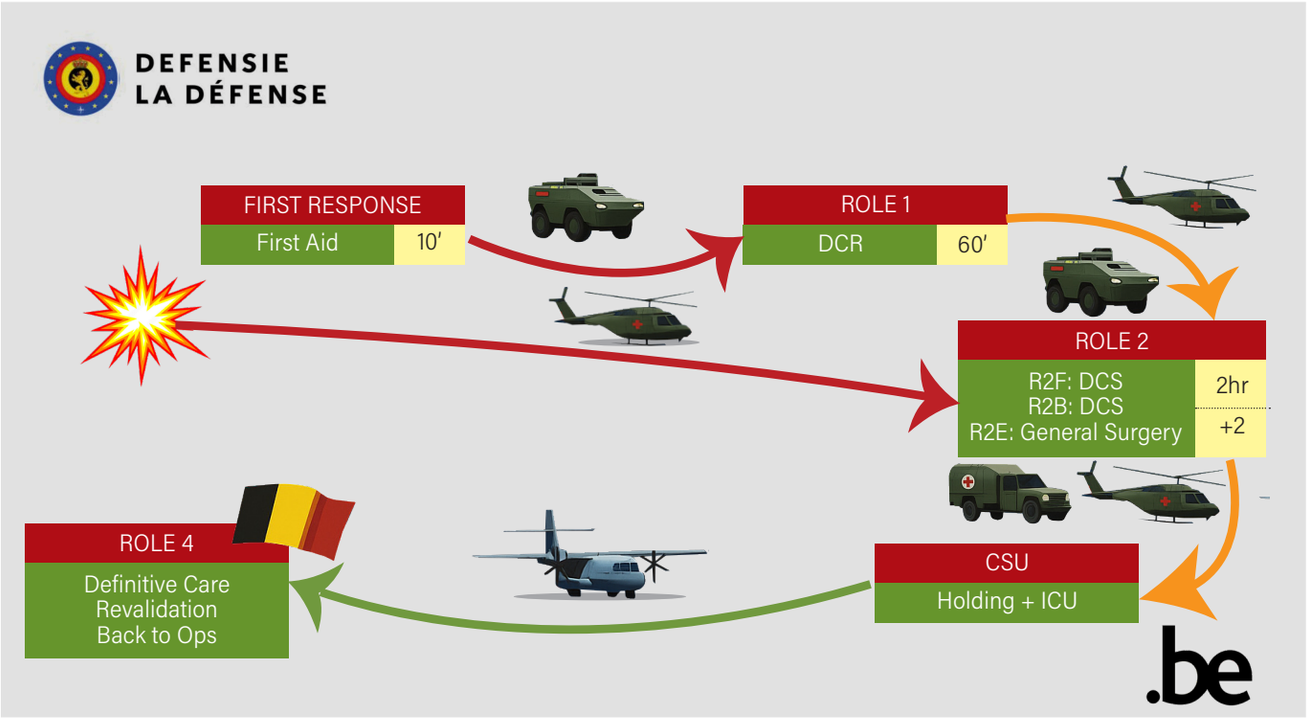
[1] NATO - Topic: Funding NATO

FIGURE 1. Employment of military nurses within the Belgian medical component.



To aid interoperability and role understanding, NATO partners developed Allied Joint Doctrine for Medical Support *(3)*. This provides scope that caters for operational contributions according to national circumstances. These range from support from independent single nations to a country contributing troops, through to a framework whereby nations cooperate based on funding, procurement, and common development. The finer detail of the nursing roles undertaken within each MTF is dependent upon the composition of nations and the role they play within the OPCP, which NATO *(3)* divides into four categories of medical deployment:

1. Medical Single Nation Concept (MSN) – one nation provides the MTF with all the relevant capabilities.
2. Medical Role Specialist Nation Concept (MRSN) – several nations collaborate to provide required capabilities.
3. Medical Lead Nation Concept (MLN) – several nations organise for a specified mission under the leadership of a single nation.
4. Medical Framework Nations Concept (MFN) – several nations organised on a permanent basis, coordinated by a framework nation.

To ensure smooth collaboration and standardisation of care and logistical processes in a MLN model, personnel from contributing nations are required to complete a programme of familiarisation with the lead nation to ease the transition into working together. This was the model applied to the Bastion Role 3 MTF in Afghanistan where US, Danish, and Estonian personnel successfully worked under UK leadership for many years. In contrast to this MLN model, the MFN concept involves the convergence of multiple national facilities working together under an appointed (and rotational) commander. Whilst these approaches provide an overall facility, the specific clinical requirements are dictated by the mission and the nations providing the specified elements under this medical framework. A further consideration is the force generation element of selecting appropriate personnel to deploy with the medical facilities. Across all four nations the decision-making process is based on the type and duration of the mission, the clinical speciality of the nurse, and the role of the MTF in the planned OPCP in the country to which they are being deployed. Table 1 shows a Belgian example of nurse speciality to role allocation.

The Australian Defence Force (ADF) advocates nurses working at the top end of their scope of practice, commensurate with their general or specialist qualifications and extended practice endorsements. However, this approach can be dynamic with wider influences. These influences include the nature of the clinical load, working within an operational coalition setting where the clinical scope of practice may differ from the domestic setting and the credentialling process. This aligns with many of the findings and studies reviewed by Sadhaan et al. who found that military nurses regularly reported significantly enhanced practice skills during deployment and a much higher rate of innovation and clinical decision-making *(18)*.

Differences in domestic healthcare systems contribute to the roles undertaken by deployed healthcare professionals. ›

› Understanding variances in healthcare systems between allies and partner nations, enables better planning and care delivery *(19)*. Undue administrative red tape from heterogeneity in roles and systems may impinge on interoperability *(19)*, whereas Sadhaan et al. highlight that military nurses have proven to be overtly adaptable to changes in roles and systems and as such flexibility should be exploited when possible *(18)*.

Clinical, support, and surge capacity

Training standards and pre-deployment competency preparations differ from nation to nation. Canadian personnel encountered interoperability challenges when deployed in 2016 to a Role 2 MTF in Iraq. The facility was augmented by clinical staff from the US, Norway, and Germany and worked closely with collocated MTFs of nine other nations (11). The Canadian nurses reported challenges associated with nurses who were deployed as individual augmentees and who were unfamiliar with Canada's drug formulary and medical equipment. This was further complicated by having to navigate nation-specific standard operating procedures that were different to their own, and echoes the concerns already described by other nations (18). The potential risk to patient safety is clear, particularly whilst also experiencing heightened operational stressors that increase the possibility of unintentional errors.

Nations working together must consider adopting the medical equipment of the lead nation or organisation that built the facility. When a different nation takes the lead in an existing MTF, transitional problems can occur. An example of this is the experience of a US medical team after they assumed the lead at Kandahar field hospital in Afghanistan. Electrical transformers were required to reduce the 220V European voltage provided, to 110V in order to safely operate the standard US equipment with which they deployed *(14)*.

Training, education, and exercises

Currently, and common across all nations, is the provision of initial nursing education leading to the award of a Bachelor's degree and Registered Nurse status. This is delivered by universities via an undergraduate programme of studies. However, with the drive to advance nursing as a profession, some universities in the UK are now offering a Level 7 'direct to Master's degree' initial nursing education programme for graduate entry, also leading to Registered Nurse status. However, although the programmes of study in each country will be broadly aligned with the registration requirements of their professional regulatory bodies, this is by no means standardised across different nations. The approach to course content can vary between nations, or in the case of Australia, even between States. While the Australian Tertiary sector is required to educate students to meet Australian Nursing and Midwifery Accreditation Council (ANMAC) standards *(20)*, there is some variance across university nursing curricula. This means that nurses graduate with largely, but not entirely, common skills and knowledge *(21)*. Extrapolate this across a multinational nursing team, and it is inevitable that there will be some knowledge and skill deficits across its workforce.

Australia utilises the additional role of enrolled nurse in its civilian clinical healthcare settings, a position not found in either the Belgian or Spanish militaries, and discontinued in the UK during the 1990s. Enrolled nurses are trained in Australia on a one-year vocational nursing course and are akin to the Health Care Assistants (HCA) employed in the British Army (there is no comparable role in the Royal Navy or Royal Air Force), reflecting a difference in nomenclature rather than role. However, recruits can also enlist directly into the ADF to train as Medical Technicians, a hybridised enrolled nurse / paramedic role. This is achieved by undertaking the 76-week Australian

TABLE 1. Belgian nurse speciality to role allocation.

Nursing Profile / Specialty	Typical OPCP employment
General Nurse (Bachelor's degree)	Role 2/3 Modular Ward/holding – CSU (Casualty Staging Unit)
Critical care nurse (specialisations: Critical care & emergency care)	Role 1 – Role 2/3 Emergency Module / Surgical Module /ICU Module / Primary Healthcare Module / Medevac Module – CSU – Ground Ambulance Unit - Special Operations Surgical Team (SOST)
Flight Nurse	Strategic & Tactical Aeromedical Evacuation Forward Aeromedical Evacuation
OR Nurse	Role 2/3 Surgical Module - SOST
Psychiatric Nurse (Mental Health)	Role 2/3 BSR (Battle Stress Recovery)
Navy Nurse	Role 1 Navy

Defence Force Medical Course (unqualified entrants) or an abridged version of the course with variable entry points for qualified entrants *(22, 23)*. Qualified enrolled nurses undergo additional paramedic training to prepare for a common Medical Technician deployed role.

Recruitment of registered nurses into the national militaries of countries included in this paper is broadly from cohorts who have graduated from civilian degree programmes. Whilst the UK recruits' direct entrants through this process, it also trains military nurses within the Service at its Defence School of Healthcare Education. However, although personnel are considered to be serving, their course is provided by a civilian university. From 2025, the Belgian Armed Forces have also adopted this model of contracting out the pre-registration education of their nurses, with military training taking place during academic holiday periods.

Another common feature of all the countries involved in this paper is the requirement for some form of transition process to allow civilian nurses to adjust to nursing in the military environment. In Spain, for example, nurses selected to join the Armed Forces are required to complete a one-year access course, after which they will enter at the (NATO standardised) rank of OF1. By contrast, in the UK, the transitional requirements are much less structured. All new UK military nurses are mandated to complete the one-week Transition to Military Practice course (TtMP) and the Defence Operational Nursing Competency (DONC) framework within their first year of military practice, regardless of their previous nursing experience.

A factor which all nations must prepare for, is the requirement to maintain operational readiness for deployment, but again there are differences in how this is achieved from country to country. Readiness is influenced by the nurse's specialty and the operational requirements of healthcare planning for the mission. The ADF, for example, use a placement process through which nurses work in civilian tertiary centres if they are unable to meet their practice needs within the Garrison setting. In the UK, there are no longer any military hospitals, so specialist and generalist secondary healthcare nurses are predominantly employed within five regional military 'Joint Hospital Group' units. These are all based at, and integrated into, large civilian National Health Service Trust hospitals. This approach supports placements in relevant operational nursing specialist areas e.g., pre-hospital care, infection prevention and control, and critical care; enabling a broad range of clinical skills and capability to be maintained. Primary healthcare specialist nurses are employed within military primary care practices, based within military units, caring for Service personnel (and their families if based overseas) to maintain community care needs.

When UK military nurses are working in units who do relatively little clinical work, having more of a military focus on managing equipment and training, they are required to spend a minimum of two weeks every six months in a clinical setting relevant to their specialism. The Belgian model takes a hybrid approach, using placements within a dedicated Role 4 hospital and postings to various units. Those in Role 1 positions are frequently posted to operational units to both integrate with the deploying team and rehearse their skills in the military setting. Post-registration education is largely focused on specialist clinical settings driven by operational requirement. Table 2 shows the availability of nursing specialisations available across the four nations included in this study.

Whilst there is common ground to support nurses to complete Masters' (L7 EQF[2]) and doctoral (L8) study, completion of specialist training may be driven by internal courses or by a modularised approach.

In the UK, Pre-Deployment Training (PDT) is based on the role of the medical unit or military platform to which nurses will be deploying. A core aim of PDT is to improve interop- ›

TABLE 2. Military nursing specialities available in the UK, Australia, Belgium, and Spain.

	UK	Australia	Belgium	Spain
Primary care nursing	▪	▪	▪	
Mental health nursing	▪	▪	▪	
Generalist nursing	▪	▪	▪	
Medical nursing	▪			▪
Surgical nursing	▪			▪
Trauma & Orthopaedic nursing	▪			
Perioperative care	▪ (RAF only)	▪	▪	
Burns & Plastics	▪		▪	
Pre-hospital care	▪		▪	
Emergency nursing	▪	▪	▪	▪
Critical care nursing	▪	▪	▪	
Aeromedical / flight nursing	▪	▪	▪	▪
Advanced Nurse Practitioner	▪	▪		
Infection prevention & control	▪			
Sexual health	▪			

[1] The European Qualifications Framework (EQF) | Europass - pan-European mapping of academic qualification levels.

erability during insertion operations or during 'relief in place' when medical teams change over *(24)*. This can be achieved by creating deploying medical teams that can effectively assume command upon their arrival and commence their duties with negligible degradation in tempo or efficacy *(25)*. During the Iraq and Afghanistan campaigns for example, a bespoke hospital training unit was constructed in a large hangar-like building in the Army Medical Services Training Centre in the UK. Its purpose was to deliver collective team training within a simulated medical facility, then assess and validate medical units' readiness to deploy in a whole 'hospital exercise,' which became widely known as HOSPEX *(26)*. This is a model was later adopted by Australian medical units due to its efficiency and success *(27)*. Improved interoperability with other nations was achieved within the Role 3 hospital at Camp Bastion in Afghanistan through a comprehensive programme of shared PDT which saw, for example, US and Danish health care teams visiting the UK to take part in HOSPEX immediately prior to their joint deployment.

Metrics and benchmarking

Future allegiances will undoubtedly need to consider how to collect, share and exploit clinical data to achieve increased health outcomes for all. The collation of operational clinical data is critical for improving situational awareness of emerging injury patterns and threats to health amongst the deployed force *(13)*. Interoperable health surveillance systems are designed for collective information gathering and sharing. One such example is EpiNATO-2, which remains the only interoperable health surveillance system enshrined in NATO doctrine. These systems are intended to "provide information for action and medical decision-making, and force health protection assurance at the local and theatre levels" *(28)*. However, in recent years this has been disputed; with Rowh et al. concluding that EpiNATO-2 fails to meet its objectives as stated above; citing poor data due to ambiguous case definitions and frequent unsubmitted reports *(29)*. New data exploitation opportunities are being developed and exercised continually and would need to be embedded across all partner nations to achieve success *(30)*. Further exploration and recommendations for future data sharing opportunities could be considered in future work.

Conclusion

Both papers in this series so far have given clear challenges and benefits to effective interoperability both for wider military outcomes and specific medical facilities. Whilst globally the role of nurse has many similarities it is important to recognise and understand the differences as well. This work must be undertaken well in advance of any collaborative operation to remove the barriers to success and unlock the potential of interoperable working *(31)*. There are fundamental differences in how nations train, educate and employ nurses both in peacetime and in war fighting operations. However, each nation still has a duty to provide evidence-based, effective, and timely care to patients regardless of their location or origin, and as such uncovering variances in care delivery early is key to developing a more structured approach to future interoperability *(32)*. The first paper in this series introduced the conceptual basis for and general and understanding of interoperability *(5)*. This second paper has used six themes to structure a review of planning considerations for delivering nursing care in the operational setting, and to enhance the conditions for successful interoperable working *(8)*. The next paper in this series will explore potential mitigations or solutions learnt from lessons in our shared past that will better equip us, as military nurses, for future conflicts and military healthcare demands.

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African Swine Fever in Germany, Spread Tendencies, Measures, Prevention and Impact on Military Exercises and Troop Movements

Peste porcine africaine en Allemagne, tendances de propagation, mesures, prévention et impact sur les exercices militaires et les déploiements des troupes

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Summary

African Swine Fever (ASF) is a listed animal disease affecting exclusively suidae. It has been spreading among the domestic and wild pig population of Eastern -and subsequently- Central Europe since 2014. An outbreak of ASF is usually followed by officially ordered biosecurity measures for the affected and surrounding area, as the socio-economic consequences can be severe. In fighting the spread of ASF, a collaborative effort of both civilian and military veterinary authorities is needed. One of the main aims following the confirmation of ASF is to prevent the spread of the virus via wildlife, forestry, agriculture and worldwide transport with the latter applying to military activities as well. In this context the sanitation of military vehicles and material moving between affected and non-affected areas needs to be carefully planned and executed. This article aims to give an overview on the pathology of African swine fever, report on historical and recent outbreak developments as well as measures of surveillance, control and prevention regarding military exercises and troop movements.

Key Words: Animal Disease Transmission, African Swine Fever, Veterinary Public Health, Transmission countermeasures, Wild Boar, Military Exercise, Military Transportation, African Swine Fever Surveillance, Carcass Detection, Carcass Search, Culling, Cleaning, Sanitation.

Résumé

La peste porcine africaine (PPA) est une maladie animale répertoriée qui touche exclusivement les suidés. Depuis 2014, elle se propage parmi les populations de porcs domestiques et sauvages d'Europe de l'Est, et ensuite d'Europe centrale. L'apparition d'un foyer de peste porcine africaine est généralement suivie de mesures de biosécurité prescrites officiellement pour la zone touchée et ses environs, étant donné que les conséquences socio-économiques peuvent être graves.
Pour lutter contre la propagation de la peste porcine africaine, les autorités vétérinaires civiles et militaires doivent collaborer. L'un des principaux objectifs après la confirmation de la présence de la peste porcine africaine est d'empêcher la propagation du virus par la faune sauvage, la sylviculture, l'agriculture et les transports mondiaux, ce dernier point s'appliquant également aux activités militaires. Dans ce contexte, l'assainissement des véhicules militaires et du matériel circulant entre les zones touchées et non touchées doit être soigneusement planifié et exécuté. Cet article vise à donner un aperçu de la pathologie de la peste porcine africaine, à rendre compte de l'évolution historique et récente des foyers ainsi que des mesures de surveillance, de contrôle et de prévention concernant les exercices militaires et les mouvements de troupes.

Mots clés : Transmission des maladies animales, peste porcine africaine, santé publique vétérinaire, contre-mesures de transmission, sanglier, exercice militaire, transport militaire, surveillance de la peste porcine africaine, détection des carcasses, recherche des carcasses, abattage, nettoyage, assainissement.

Introduction

ASF is a notifiable animal disease caused by African Swine Fever Virus (ASFV) of the Asfarviridae virus family. It exclusively affects suidae, both wild boar and domestic pigs are susceptible. ASFV is an enveloped double stranded DNA-virus 200-300 nm in size. It is highly resistant to environmental conditions especially in dry and cold weather and can survive in raw pork products up to four months and in bone marrow or carcasses up to seven months. Inactivation occurs at temperature levels above 69°C, very low (<3.9) or high pH values (>11,5), gamma radiation or appropriate chemical treatment.[1]

The virus originates from sub-Saharan Africa where it is transmitted in a sylvatic cycle among warthogs and soft ticks of the Ornithodoros genus. The infection in warthogs is usually not accompanied by clinical signs nor overall increased mortality.

Among the Eurasian wild boar and domestic pig population, where the virus was only introduced in 2007, virus transmission is mostly animal to animal contact related, but indirect transmission also occurs (for example via ingestion of raw pork products).

In Europe, clinical symptoms may vary, depending on virulence of the virus strain and immune status of the animals. Peracute

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and subclinical courses are possible, but due to a mostly innocent population and high virulence of the circulating strains an acute disease with severe symptoms currently presents as the most common: after an incubation period between three to 15 days- the infection leads to an acute illness with up to 90% lethality in both domestic pigs and wild boar. The most common symptoms are fever, respiratory as well as gastrointestinal symptoms, hemorrhage (Pig Ebola), blue skin, movement disorders, somnolence and – in almost all of the affected animals- neurological seizures and finally death. Post mortem-findings often show enlarged ebony-colored lymphnodes as well as petechial hemorrhages in organs like kidney and liver in addition to disruption of the gastrointestinal mucous membranes and lung edema.

Typically, not all of the animals are infected: an only moderate contagiosity is accompanied by nearly 90% lethality. Thus, an uncontrolled outbreak in wild boar usually leads to the establishment of the virus among the population, as enough animals initially stay healthy and the carcasses of the diseased, carrying the viable virus, provide a source of infection for a long time. Hence, in a natural environment the infection is not self-limiting.

Because of the socio-economic consequences, strict governmental measures and trade restrictions are put in place, following the confirmation of an outbreak of ASF. These restrictions itself may have a harsh influence on local forestry, agriculture and meat production businesses, but try to avert further damage from the overall economy.



Fig. 1. Skin hemorrhages



Fig 2. petechial hemorrhages kidney © Friedrich-Loeffler-Institute

Outbreak History:

ASF is of African origin and was first described in areas south of the Sahara Desert. As a natural reservoir African wild boar species like warthog and bush pig as well as African leather ticks were identified. In these species, the virus is able to persist without causing symptoms. The first description of ASF occurred in Kenia 1921[2], when the virus transferred from African wild boar to domestic pigs originating from Europe and farmed in colonial settlements. African swine fever itself reached Europe in 1957 when it was detected in a Portuguese pig farm. This outbreak was quickly controlled, but the virus reappeared in Portugal just three years later, spreading to Spain and France this time. From the 1960s to the 1990s when the virus was present in Spain, short episodes of outbreaks were also reported in France, Malta, Belgium and the Netherlands due to food trading and poor feeding practices. In 1978 the virus was introduced to Sardinia, where it is still present. With the exception of Sardinia, where Ornithodoros leather ticks are indigenous and the outbreak developed to an autochthone self-sustaining infection cycle, ticks are not a part of the reproduction cycle and measures were successfully put in place to extinct the outbreaks in the named countries. In the 1980ies a South American outbreak hit Cuba, Brasilia, the Dominican Republic and Haiti with a successful extinction of the disease there as well. However, the virus has reemerged in the Dominican Republic and was present from July 2021 until the end of December 2022.[3]

By now ASF has been or is present on every continent of the world. Since being introduced to Georgia via merchant ships in 2007 and subsequently spreading throughout the transcaucasian region we are experiencing the so-called Caucasian outbreak in Europe just now.

Starting in Georgia, South Russia, and Armenia the velocity of the propagation of the disease was around 5 km per year. Since 2020 a slightly quicker propagation velocity has been noted. The specific reasons for this increase in velocity are yet unknown, but virus mutation, slower disease onset ›

› and progress as well as high density of wild boar population are discussed.

In 2013 Northwest Russia and Ukraine were affected by ASF for the first time, followed by the Baltic States in 2014. After a massive spread there, the first outbreak was confirmed in Poland at the Belarussian border. Until 2018 infection rates rose steadily in those Nations. In addition, the disease reached the Peoples Republic of China in August 2018 and has been spreading on the Asian continent until today.

In Autumn 2018 a single (spot-infection) outbreak in Belgium occurred. Suspicions were voiced about transmission by military vehicles, but Belgium military could prove that NATO cleaning and sanitation protocols had been strictly followed before transportation.

The first ASF outbreak in wild boar in Germany was confirmed on the 10th of September 2020 in the rural district Spree-Neisse, Brandenburg, near the Polish border at a time when ASF had already been present in wild boar in the adjacent part of Poland. Measures were executed immediately, but as the infected wild boar carcass had been found in an advanced state of decay, further spread amongst the wild boar population of Germany had already occurred and several more cases were subsequently detected in the vicinity.

As a first measure restriction zones needed to be established and soon expanded, as more and more cases among wild boar were confirmed. On the 31st of October 2020 the first case of ASF in wild boar was confirmed in Saxony. In addition to the spread from the borders, two outbreaks in wild boar, retrospectively classified as spot infections occurred in Germany: October 2021 in the area of Meissen/Dresden (Saxony) as well as November 2021 in the rural district of Ludwigslust-Parchim in Mecklenburg-Western Pomerania close to the Brandenburg border.

As result of the established countermeasures in Germany, cases in wild boar decreased from 1600 in 2022 to 887 in 2023. In 2024 84 cases have been reported by the middle of May. Restriction zones in Brandenburg have been lifted and reduced in size.

Military installations affected by outbreaks:

Overall, nine military properties of the Bundeswehr have been a part of ASF-restriction zones. After several zones have been lifted, three of them still remain inside restriction zones as of today. The largest of them, the Military Training Area (MTA) Oberlausitz is located in Saxony, close to the Polish border and -with 16,800 hectares- is the third largest Bundeswehr MTA in Germany. The military significance of MTA OBERLAUSITZ is derived from its unique landscape profile of extensive forest as well as vast dune areas, which provides ideal conditions for the deployment of armored troops as well as live firing with high-value weapon systems, such as combat helicopters.

The Bundeswehr has been conducting a monitoring program for emerging wildlife diseases at selected MTAs since 2014. This included the sampling and examination of wild boar shot during social hunts for Classical and African swine fever. Since the first outbreak of ASF in Germany, all Bundeswehr sites have been subjected to increased monitoring and all wild boar shot or found dead have been examined.

Following the first outbreak in Saxony which occurred only meters from the border of the MTA, the Training Ground Oberlausitz has been partially inside the restriction zones. Exercise operations on the MTA were initially completely suspended and only resumed almost a year later in September 2021 after risk assessment of individual exercise projects and the establishment of comprehensive prevention and control measures. The first outbreak on the training ground itself was confirmed on the 18th of February 2021.

The control of ASF on the military training grounds is carried out in close cooperation with the locally and professionally responsible military and civilian authorities (ministries, districts and veterinary offices).

For MTA Oberlausitz this meant the immediate fencing of the larger Eastern part of the training ground to prevent immigration of wild boar from the east, monitoring of the wild boar currently present using both wildlife cameras and drones, the reduction of said animal population using both hunting and culling methods plus the reduction of the infective agent via extensive carcass searches. Furthermore, as the MTA is normally not only used by troops from all over Germany, but also by armed forces of allied nations, cleaning and disinfection measures were put in place for all vehicles and material used on the MTA off paved roads. Initially all exercises were suspended and only allowed to recommence almost one year later, when all measures had begun to take effect.

Measures under military consideration:

Drones

At MTA OBERLAUSITZ civilian drone technology was initially used to assess the wild boar population and to determine the day- and night-time locations of the animals. Subsequently it was also used for carcass searches and assisted hunting, identifying wild boars and carcasses via zoom and thermal imaging without living animals being disturbed by the drone.

In our experience the team operating the drones should be backed up by at least one person with professional hunting/wildlife experience. Ideally all controllers monitoring the flight visuals should have a hunting license or similar experience in addition to their technical skills.

Military drone systems were also evaluated in both theory and practice tracking live animals and carcasses, but were found not to be suitable for theses specific tasks.

Trapping

Trapping is a method for culling entire packs of wild boar at once. This method represents an animal disease control measure for rapid and effective population decimation.

The classic boar trap consists of a rigid steel grid cage, with a steel grid trap door. Anchoring of the cage in the ground is necessary to prevent the whole trap from being levered out by larger boars. After the trap is erected, an initial habituation phase follows, in which the trap door is secured in an open position. In this phase the target species is attracted with preference food. After trap habituation, the trap door is activated and triggered under direct visual or video control when the animals are in the trap. As the door is rigid and heavy there is a substantially risk of trapping especially younger boar underneath the door. When the trap door is triggered using video control the risk is even higher, because of time delays in network connections[4].

After closing the trap, the animals are killed inside as soon as possible.

At MTA OBERLAUSITZ, several mobile net traps (Pig Brig Trap®) have been used for removal since the beginning of 2022.

This equipment had already been scarcely used in the civilian sector for wild boar population reduction but still had proven its worth[4]. After several weeks of operation on the MTA, clear advantages could be ob-



Fig. 3. PigBrig®-Trap ©Bundesforstbetrieb Lausitz (Hr. Graf v. Plettenberg)

served in terms of user-friendliness, occupational safety and animal welfare aspects: The net trap is basically used in the same way as the classic boar trap, but due to its unique design offers many advantages. During the habituation phase at first only the fence posts are present. Later the net is hung up high, so the animals can move in and out of the trap freely. During the active phase the net is lowered to the ground, anchored and folded inwards [see Fig.3.] so the animals can still move in, but not out anymore.

Another advantage is that it is significantly easier to assemble and relocate. Regardless of which system is used, one of the most important aspects contributing to successful trapping is the location of the trap. The PigBrig® net trap can be moved promptly and with little manpower, in case a selected trap site in retrospect proves to be unsuitable or is not accepted by the animals during the habituation phase.

Most importantly, the risk of injury to the animals is much lower due to the flexible parts and the absence of a door. Furthermore, even when the trap is armed, animals can still follow the pack from outside, which reduces the stress level of the animals.

Last but not least, there is also a reduced risk of injury for the hunters due to the net, as the risk of stray bullets ricocheting off course is minimized by the small number of rigid parts.

Prophylactic Measures – Cleaning and Disinfection

As mentioned before, MTA OBERLAUSITZ is not only used by troop units throughout Germany, but also by allied nations. To prevent the spread of the ASF virus to unaffected parts of the country or abroad, a strict cleaning and disinfection regiment had been established for vehicles and material used at the MTA before use was granted again. All material and vehicles leaving the training area are cleaned and - if used on unpaved roads or in the field - disinfected. Special care is taken to remove all soil deposits.

As the disinfection time and efficiency is subject to temperature und other weather conditions, a large tent has been erected on site, which can be heated to an appropriate temperature during the winter. The disinfection solution is distributed to the material via a foaming system to ensure better adhesion to the material. As the exercises maneuvers especially with the vehicles can be intense and tanks often reach the cleaning point covered in mud, scaffolding has been erected inside the tent, to make sure all parts of the vehicles can be reached.

The same measures are applied during international movement. For Deployment adherence to the guidelines of the target or transit country are followed. For Redeployment the risk of ASF transmission is assessed by operation assigned senior veterinary officers and the necessary measures determined by German Military Headquarters. As the Baltic states are common ground for military exercises and ASF is widely spread among the wild boar population in these countries, prophylactic measures are required before Redeployment to Germany.

Conclusion

The animal disease prophylactic surveillance of Bundeswehr properties and the order of appropriate measures for control in the event of an animal disease pose a great challenge. Animal welfare and species protection aspects have to be considered and implemented as well as the restrictions for the exercising troops have to be kept as low as possible. This requires intense coordinated action between the civilian and military veterinary authorities, the Federal Forestry Service, the MTA commander and the exercising troops. In doing so, it is important to know the respective priorities of the individual parties concerned and to take them into account in an appropriate manner.



Fig. 4. Tank chain during disinfection © V. Steudel

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When Silence Speaks

The ICMM's Ethical Obligation to Address Humanitarian Violations in Contemporary Armed Conflicts

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1. Introduction: A Question That Must Be Asked

Between 2008 and 2015, I had the privilege of serving as Commandant of the ICMM's International Course on Military Medical Ethics and the Law of Armed Conflict. During those years, I worked with military medical personnel from all regions of the world—from Majors to three-star Generals—representing armed forces of vastly different traditions, resources, and operational contexts.

It is precisely this experience—and this deep respect for the ICMM's historical role—that compels me to ask a difficult question: In the present moment, when documented evidence of systematic humanitarian violations emerges from multiple conflicts worldwide, what is the ICMM's responsibility?

I write this article not as a critic standing outside, but as someone who devoted years to building the ICMM's educational infrastructure in military medical ethics. My purpose is not to point fingers at any specific conflict or party, but to argue for a principle: that the ICMM's neutral status is not an excuse for silence, but rather the very foundation that enables and obligates it to speak.

Quand le silence parle

L'obligation éthique du CIMM de répondre aux violations humanitaires dans les conflits armés contemporains

Abstract

The International Committee of Military Medicine (ICMM), with its 113 member states and unique neutral mandate, represents arguably the most significant international forum for military medical services. Yet in an era of documented, systematic violations of humanitarian norms—including attacks on medical facilities, mistreatment of prisoners, and the deliberate erosion of medical neutrality—the question must be raised: Does institutional silence constitute complicity? This article argues that the ICMM's founding mission not only permits but requires the organisation to issue clear, universal reaffirmations of humanitarian principles to all parties in contemporary conflicts.

Drawing on experience from seven years directing the ICMM's Reference Centre for Education in International Humanitarian Law and Military Medical Ethics, and building on ethical analysis of torture and state degradation, I contend that armed forces that systematically violate LOAC ultimately destroy themselves from within—transforming from disciplined military institutions into undisciplined armed groups. The ICMM possesses both the authority and the responsibility to remind all member states of this truth.

Keywords: Military medical ethics · humanitarian law · institutional silence · moral cohesion · torture

Résumé

Le Comité international de médecine militaire (CIMM), fort de ses 113 États membres et d'un mandat de neutralité unique, représente le forum international le plus important pour les services de santé des forces armées. Pourtant, à une époque marquée par des violations systématiques et documentées des normes humanitaires — notamment des attaques contre des installations médicales, des mauvais traitements infligés aux prisonniers et l'érosion délibérée de la neutralité médicale — la question doit être posée : le silence institutionnel constitue-t-il une complicité ? Cet article soutient que la mission fondatrice du CIMM non seulement autorise, mais exige de l'organisation qu'elle émette des réaffirmations claires et universelles des principes humanitaires à l'égard de toutes les parties dans les conflits contemporains. Fort de sept années d'expérience à la direction du Centre de référence du CIMM pour l'enseignement du droit international humanitaire et de l'éthique médicale militaire, et en s'appuyant sur une analyse éthique de la torture et de la dégradation étatique, l'auteur soutient que les forces armées qui violent systématiquement le DICA se détruisent de l'intérieur — se transformant d'institutions militaires disciplinées en groupes armés indisciplinés. Le CIMM possède à la fois l'autorité et la responsabilité de rappeler cette vérité à tous ses États membres.

Mots-clés : éthique médicale militaire · droit international humanitaire · silence institutionnel · cohésion morale · torture.

2. The Nature of ICMM Neutrality: Enabling Voice, Not Justifying Silence

A common misunderstanding equates neutrality with silence. This is a fundamental error. The International Committee of the Red Cross—an organisation whose neutrality is beyondquestion —regularly issues public statements reminding all parties to conflicts of their humanitarian obligations. These statements do not compromise ICRC neutrality; they fulfil the ICRC's mission.

The ICMM's neutrality should function similarly. It is precisely ›



The Nuremberg Doctors' Trial (1946–1947) — "United States of America v. Karl Brandt, et al." The defendants under guard in the dock. Source: United States Holocaust Memorial Museum/ Wikimedia Commons, Public Domain

› because the ICMM does not represent any single nation or political bloc that it can speak with moral authority to all.

The question is not whether the ICMM can issue such statements without compromising its neutrality. The question is whether it can fail to issue them without compromising its mission.

3. Why Humanitarian Violations Destroy the Violators

Armed forces that systematically violate humanitarian norms do not merely harm their victims—they destroy themselves from within. This is not merely a moral argument. It is an empirical observation supported by historical evidence and psychological research.

3.1 The Dehumanisation of the Perpetrator

As George Annas observed: 'Torture begins by dehumanising the victim but ends by dehumanising the torturer.' Soldiers who engage in systematic violations lose their capacity for empathy and their ability to distinguish legitimate military action from acts driven by anger, fear, or cruelty.

3.2 The Erosion of Command Authority

When commanders tolerate or encourage violations of LOAC, they undermine the very foundation of military discipline. The chain of command—essential for any military operation—begins to fracture.

3.3 The Transformation into 'Soldateska'

An armed force that allows humanitarian violations risks internal moral collapse. It ceases to function as a disciplined military institution and acquires characteristics of a wild soldiery.

3.4 The Destruction of State Institutions

A state whose security forces engage in systematic torture creates citizens who cannot trust their own institutions. This represents not merely a moral failure but a strategic one.



Facsimile of the first Geneva Convention of 1864 — the foundation of international humanitarian law. Source: Wikimedia Commons, Kevin Quinn, CC BY 2.0



Neutrality and Humanitarian Engagement — The International Committee of the Red Cross in Geneva.

4. The Stabilising Role of Military Medical Services

Military medical services play a crucial role in preventing moral erosion. Their commitment to impartial care, humane treatment, and strict adherence to LOAC acts as an ethical anchor within armed forces. Medical personnel embody the principle that even in war, there are limits—and that these limits are an expression of military honour, not a constraint upon it.

The ICMM, as the global forum for military medical services, has both the standing and the responsibility to articulate this truth clearly and consistently.



"Even in war, minimum basic humanitarian principles must apply"

— Hans U. Baer



"Military Medical Care in the Field — the Humanitarian Foundation of the Armed Forces."

5. A Call to Action: What the ICMM Can and Should Do

5.1 Universal Reaffirmations

The ICMM should issue regular, universal statements reaffirming the applicability of humanitarian principles to all parties in all conflicts—without singling out specific nations or parties.

5.2 Educational Intensification

The ICMM should expand its educational programmes to explicitly address the self-destructive consequences of humanitarian violations.

5.3 Visible Commitment

The ICMM's commitment to humanitarian principles should be visible and continuous, not merely implicit.

6. Conclusion: The Cost of Silence

The ICMM itself faces a duality. It must maintain its neutral status to preserve its unique role as a platform for dialogue across political and national boundaries. But it also has an obligation to the principles that justify its existence—the conviction that humanitarian norms in armed conflict are universal, non-negotiable, and essential.

The question for the ICMM is not whether it can speak. The question is whether it can afford to remain silent.

Declaration

The views expressed in this article are solely those of the author and do not represent the official position of the Swiss Armed Forces or any other institution.

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Comparing Age determination of Individuals between 15 and 26 years old using radiograph of developing teeth and Artificial Intelligence face recognition.

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ABSTRACT

Background:

The aim of this study is to determine the relationship and accuracy of two different age estimation methods in young adults between 15 and 26 years, estimation of the age based on measurement of open apices in wisdom teeth and estimation of the chronological age with artificial intelligence facial recognition software.

Patient and Methods:

24 individuals between 18 and 26 years were randomly selected at the Belgian Air Force Base Beauvechain (Belgium) and 59 individuals were selected at an orthodontic office in Kortenberg (Belgium) of which 29 were under 18 years and the other 30 adults were older than 18 years. One researcher (TV) took a radiograph and a facial photo from an individual. The other two researchers (PVS & MN) at the military hospital Queen Astrid (Brussels, Belgium) evaluated the radiographs. Two smartphone applications for age estimation that leverage artificial intelligence also generated an age estimation. Results and accuracy of the three methods were compared with the chronological age of the individuals. The differences in age estimation error between the two methods was evaluated using a repeated measures ANOVA. The performance related to correctly identifying an individual as a minor (i.e. <18 years of age) was evaluated by considering this as a binary classification problem.

Results:

The chronological mean age of all participants was 19.88 years. From 83 radiographs, only 52 were used because 20 individuals had no or few wisdom teeth. An additional 11 participants were not included in the study because, according to the method used by the Belgian Army using radiological images is 20.62 years with a standard deviation of 1.49 years. For participants older than 22.11 years the difference between the chronological and estimated age becomes increasingly greater. For the AI programs, all photos were used.

The radiological method yielded a mean absolute age error (MAE) of 1.37 years and a root mean squar error (RMSE) of 1.67 years. The commercial AI program yielded an MAE of 2.55 years and a RMSE of 3.32 years. Difference to calculate age was not significant with the chronological age. The age estimation measurements (2.73 years) of the free software had a significant difference from the chronological age.

When comparing the MAE with the RMSE, we see a smaller deviation for the radiological method (20%). For the AI software, the deviations are 30 and 34%, respectively. The differences between MAE and RMSE shows that in the AI method there are larger outliers in the age estimation.

A repeated measures ANOVA showed differences of age errors across the three estimation methods ($F(2,102)$, $p<0.001$, $\eta^2=0.189$). Moderate differences occurred between the radiological method and the free AI program ($p<0.001$, $d=0.797$), and large differences between the commercial program and the free AI program ($p<0.001$, $d=0.930$). No significant difference was observed between radiological and commercial program ($p=0.37$). Regarding the problem of correctly identifying an individual as a minor, the radiology method offers the best performance (F1-score of 0.82), followed by the commercial AI program (F1-score of 0.81), and finally the free AI program (F1-score of 0.46). The radiology method appears to be the most performant method when considering age prediction. The same also holds when considering the classification performance.

Conclusion:

The objective of the study was to identify and classify individuals into minor or adult age groups for medicolegal purposes. Two different methods were compared; radiologically or by AI. As a conclusion the commercial AI program can be used as an alternative when dental records are not available. It is however important to underline that MAE (Means Absolute Age error) and RMSE (Root Mean Squared Error) are substantially larger when compared with the radiological method. Some caution is advised for critical cases. The free software performs the worst of all in all evaluated applications. When subjects come without wisdom teeth, the AI software is a reliable alternative to the radiologic method.

Keywords:

Forensic odontology, chronical age determination, artificial intelligence age determination, age estimation, facial age estimation.

Comparaison de la détermination de l'âge des individus âgés de 15 à 26 ans à l'aide de radiographies des dents en développement et de la reconnaissance faciale par intelligence artificielle

TOM VERHOFSTADT, MATTHIAS NEUKERMANS, BART DE CLERCK - BELGIUM

RÉSUMÉ

Contexte :

L'objectif de cette étude est de déterminer la relation et la précision chez les jeunes adultes entre 15 et 26 ans, avec deux méthodes différentes : l'estimation de l'âge basée sur la mesure des apex ouverts des dents de sagesse et l'estimation de l'âge chronique avec un logiciel de reconnaissance faciale à intelligence artificielle.

Patients et méthodes :

24 individus entre 18 et 26 ans ont été sélectionnés au hasard à la base aérienne belge de Beauvechain (Belgique) et 59 individus ont été sélectionnés dans un cabinet d'orthodontie à Kortenberg (Belgique) dont 29 avaient moins de 18 ans et les 30 autres adultes avaient plus de 18 ans. Un chercheur (TV) a pris une radiographie et une photo du visage d'un individu. Les deux autres chercheurs (PVS & MN) de l'hôpital militaire Reine Astrid (Bruxelles, Belgique) ont évalué les radiographies. Deux applications pour smartphone d'estimation de l'âge qui exploitent l'intelligence artificielle ont également généré une estimation de l'âge. Les résultats et la précision des trois méthodes ont été comparés à l'âge chronologic des individus. Les différences d'erreur d'estimation de l'âge entre les deux méthodes ont été évaluées à l'aide d'une ANOVA à mesures répétées. La performance liée à l'identification correcte d'un individu comme mineur (c'est-à-dire < 18 ans) a été évaluée en considérant cela comme un problème de classification binaire.

Résultats :

L'âge moyen chronologique de tous les participants était de 19,88 ans. Sur 83 radiographies, seulement 52 ont été utilisées car 20 individus n'avaient pas ou peu de dents de sagesse et 11 participants supplémentaires étaient trop âgés pour estimer l'âge avec cette méthode. Pour les programmes d'IA, toutes les photos ont été utilisées.

La méthode radiologique a donné une erreur absolue moyenne d'âge (MAE) de 1,37 an et une erreur quadratique moyenne (RMSE) de 1,67 an. Le programme d'IA commercial a donné une MAE de 2,55 ans et une RMSE de 3,32 ans. La différence pour calculer l'âge n'était pas significative avec l'âge chronologique. Les mesures d'estimation de l'âge (2,73 ans) du logiciel gratuit présentaient une différence significative par rapport à l'âge chronologique.

Lors de la comparaison du MAE avec le RMSE, nous observons un écart plus faible pour la méthode radiologique (20 %). Pour le logiciel d'IA, les écarts sont respectivement de 30 et 34 %. La différence en pourcentage entre le MAE et le RMSE montre que dans la méthode d'IA, il existe des valeurs aberrantes plus importantes dans l'estimation de l'âge.

Une ANOVA à mesures répétées a montré des différences d'erreurs d'âge entre les trois méthodes d'estimation ($F(2,102)$, $p<0,001$, $\eta^2=0,189$). Des différences modérées sont apparues entre la méthode de radiologie et le programme d'IA gratuit ($p<0,001$, $d=0,797$), et de grandes différences entre le programme commercial et le programme d'IA gratuit ($p<0,001$, $d=0,930$). Aucune différence n'a été observée entre le programme radiologique et le programme commercial ($p=0,37$).

En ce qui concerne le problème d'identification correcte d'un individu comme mineur, la méthode de radiologie offre la meilleure performance (score F1 de 0,82), suivie du programme d'IA commercial (score F1 de 0,81) et enfin du programme d'IA gratuit (score F1 de 0,46).

La méthode de radiologie semble être la méthode la plus performante en ce qui concerne la prédiction de l'âge. Il en va de même pour les performances de classification.

Conclusion:

L'objectif de l'étude était d'identifier à des fins médico-légales les individus âgés de moins de 18 ans ou de plus de 18 ans. Les 2 méthodes différentes ont été comparées.

En conclusion, le programme d'IA commercial peut être utilisé comme alternative lorsque les dossiers dentaires ne sont pas disponibles. Il est cependant important de souligner que le MAE et le RMSE sont sensiblement plus élevés par rapport à la méthode de radiologie. Une certaine prudence est de mise pour les cas critiques. Le logiciel gratuit est le moins performant de toutes les applications évaluées. Lorsque les sujets n'ont pas de dents de sagesse, le logiciel d'IA est une alternative fiable à la méthode radiologique.

Mots clés:

odontologie médico-légale, détermination de l'âge chronologique, détermination de l'âge par intelligence artificielle, estimation de l'âge, estimation de l'âge facial.

INTRODUCTION

Several papers in the field of forensic odontology and archaeology deal with estimating chronological age in humans. Image-based age and age group estimates have today enormous applications for military, security and surveillance and to improve homeland security *(5)*. As immigration and the number of refugees around the world and in particular in Europe increase, the demand for rapid and secure age estimation is growing *(6)*.

The aim of this study is to determine the relationship and accuracy in young adults between 15 and 26 years, with two different methods: age estimation based on measurement of open apices in wisdom teeth and estimation of the chronological age with frontal facial clinical photos.

The difference between chronological and dental age and chronological and estimated age was calculated for each individual and each method. The accuracy of each method was assessed using the mean absolute error (MAE) in years between chronological and estimated age.

In the context of legal age determination (plus or minus 18 years old) a comparison was taken between both methods; i.e. radiological measurement and AI age estimation.

Until now many methods in forensic dentistry many methods have been derived and modified based on the Demirjian method, which was first described in 1973 *(1)*. It allows for subjective judgment by observers, and its wide error range is still an issue.

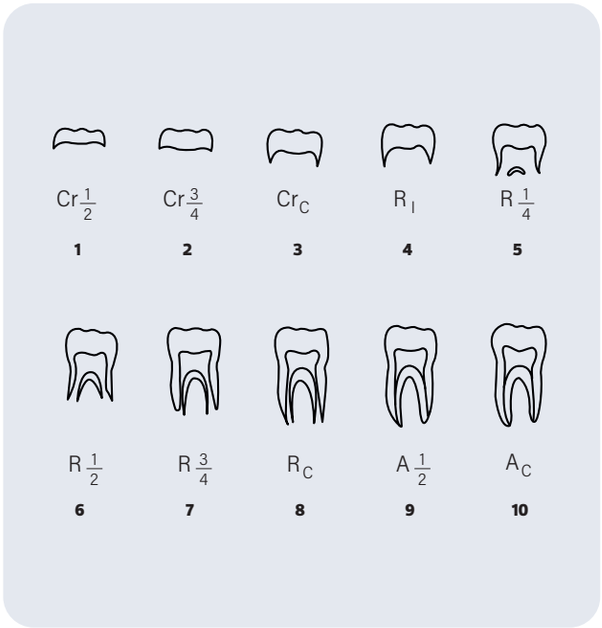
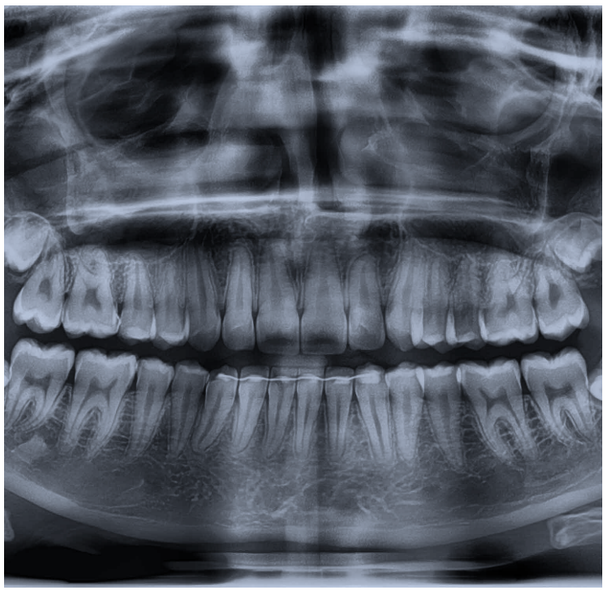


FIG. 1: Developmental stages according to a modification of the technique by Gleiser and Hunt. Each developmental phase of the third molar evaluated has a score ranging from 1 to 10. When calculating the chronological age, this score must be used for the corresponding third molar in the selected regression formula *(3)*.



Example of a panoramic radiograph of a female of 17.60 years old. The 10-stages development method calculated an age of 16.64 +/- 1.51 years.

Despite significant advances and sample work in related research areas, a 100 % accurate and effective method for age determination in young adults has not yet been achieved.

Teeth are considered a reliable biological marker of aging as they are highly durable, resistant to putrefaction, fire, and chemicals. Compared with an assessment of the ossification stage of the medial clavicular epiphysis in bone development, dental development, and eruption of the wisdom teeth provides a reliable indication of chronological age *(2)*.

Commonly utilized dental methods in children and adolescents include the analysis of dental development, tooth eruption, the mineralization of the tooth crowns and roots and open apices of the root *(3)*.

Radiographs meeting these selection criteria were evaluated using a 10-stage developmental scoring method as was proposed by Köhler et al. *(16)*. Each of the 10 stages relates to a particular developmental phase (fig. 1). All of the third molars present on the radiograph were given a score corresponding to the stage of root development. In the case of a different developmental stage of the multiple roots of a third molar, the least developed root was evaluated and scored.

The last decade, continuous efforts to improve the accuracy of AI-based estimations, one of which is the incorporation of deep learning algorithms, have been made. Convolutional neural networks (CNNs) have been reliably used for various problems in the dental field, for example using dental X-ray images *(4)*. Also, for forensic and medico-legal purposes in age estimation is important *(7)*. The role of age estimation in age simulation ›

› goes a step further in helping identify missing persons. Age simulation can also be used to identify people from their previous images for identification purposes.

Materials and Methods

A prospective observational study was conducted with 83 participants aged between 15 and 26 years old. Frontal facial photos and panoramic radiograph were taken from each participant. The context includes soldiers seeking dental fitness classification and young adolescents at the end of orthodontic treatment. The results from both methods were be statistically compared.

This study compares deep learning systems that provide a fully automated model for age determination with face recognition on one hand and dental development on radiographs on the other. Facial photos of 83 individuals of the Caucasian type between 15- and 26-year-old were taken with a smartphone, iPhone 12, Apple Inc, Cupertino, CA, USA. The photos were evaluated in a free to use AI face estimation program; Check my age from Neurotechnology (Laisses pr. 125A, Vilnius, LT-06118, Lithuania) and 1 commercial AI face estimation program Yeti (www.Yoti.com) Yoti Ltd., 6th Floor, 107 Leadenhall St, London, EC3A 4AF. In the same patients, panoramic radiographs, Vatech, (Gyeonggi-do, South-Korea) were taken and evaluated based on the dental development of the wisdom teeth. Both results were statistical compared.

To exclude bias, the panoramic radiographs were evaluated by two experienced military dentists, who perform the age determination of refugees for the Belgian Ministry of Justice. This result is compared with the findings of 2 AI Programs. From 83 individuals no comparison could be made in 20 individuals because no wisdom teeth were present, and 11 individuals were excluded because the difference between the chronological and estimated age becomes increasingly greater with third molar root development method that determines the age up to 22.11 years *(3)*. As a result, we could compare 52 individuals.

Ethical and legal considerations

There are understandable concerns about the potentially unlawful use of personal and biometric data by governments and companies.

The used AI program facial age estimation technology complies with EU GDPR ethical standards of user data and privacy. When customers use facial age estimation to verify the ages of their users, the AI program acts as the data processor and the researchers are the data controllers.

Facial age estimation does not include data processing. This is because the age estimation model is unable to allow or confirm the unique identification of a person because the program is not programmed to do so.

Therefore, it cannot be used for identification purposes in a legal or criminal context. Simply put, if you put the same face into the model multiple times, the model has no idea that it is the same face.

The study was approved by the ethics committee of the Brugmann Hospital (Ref.: CE2024/78) and was in accordance with the principles outlined in the Declaration of Helsinki. Owing to the non-interventional retrospective design of this study and because all data were analyzed anonymously, the IRB (Institutional Revieuw Board) waived the need for individual informed consent, either written or verbal, from the participants.

Face dataset creation

A frontal face images of each patient was collected. All patients provided consent for their images to be used in the study. Lighting conditions were uniform during the face image acquisition, and the patients were required to be in a standing position, without makeup on the face. None of the patients had a fever or stayed up late in the week before nor were experiencing tiredness at the time of the photography. The entire face and neck were exposed during the shooting, and the facial muscles were in a relaxed state.

Each patient's face image was collected including gender and age. There were 83 patients with ages ranging from 15 to 26 in the final face dataset. Table 1 presents the included patients' gender and age distributions. An iPhone 12 camera, was used to capture the images.

TABLE 1: Gender and age distributions of the patients.

	15–18	18–26
Female	19	18
Male	12	34
Total	31	52

It is expected that the AI method will be useful for verifying the age in forensic, medico-legal and various anthropological issues.

Artificial Intelligence Age Identification

Certain face landmarks are required for face orientation that is required for facial registration. Face alignment utilizes the eye position and the center point in the face *(8)*.

A person's face carries a great deal of information, including individuality, emotion, attitude, maturity level, ethnicity, race, and gender.

There exist two kinds of facial age estimation: biological or real age estimation, where biological age estimation determines the precise chronological or biological age of a person *(9)*, and apparent age estimation is focused on "how old does a person looks like". As a result, the real age may differ from the apparent age of a person.

Apparent age is believed to be consistent with actual age, although there are variations due to the stochastic nature of aging between individuals. Uncontrollable and personalized age information displayed on faces further complicates the age estimation problem *(10,11)*.

There are just few available age databases with a substantial number of labelled face images.

In this study we have 2 software programs that works with APPA-REAL database annotations, the only one available containing a large number of both real and apparent ages by introducing an additional set of attributes.

TABLE 2: Age-estimation related dataset.

Database	# of faces	Age range	Age type	Environment
APPA-REAL	7,591	0-95	Real and Apparent Age	Uncontrolled

Facial age estimation based on deep learning

Recently, Convolutional Neural Network (CNN) methods have been employed in the current age estimation analysis. Deep learning and CNN as a learning-based feature representation methods, have been compelled to learn discriminative feature representation directly from raw pixels and acquired linear feature filters needed to project face images into another feature space (12). The CNN architectures possess the ability to extract facial features distinctively and robustly from the face image *(14)*.

However, attempts to further improve the correctness of age estimation are still being done and researchers keep studying different (CNN) approaches to further improve results.

Deep learning and CNN have the ability to learn discriminative trait descriptors directly from image pixels *(13)*. These traits are needed to correctly estimate the age of people. CNN architecture, like AlexNet, GoogLeNet, VGGNet, ResNet, SqueezeNet and Xception are generally considered as the most common architectures because of their state-of-the-art performance on age estimation task.

Deep neural networks consist of multiple layers of neurons. The inputs to the neurons are combined with weights that amplify or reduce the input. Each neuron assigns a weight to its input – how correct or incorrect it is relative to the task at hand. The products of these are added and the sum is passed on to determine whether and to what extent the signal is continued through the network.

The output of each layer is simultaneously the input of the next layer. By combining weights with input, the network can classify and cluster this input. Deep learning networks end in an output layer or a classifier that provides the probability of a certain result. The final output is determined by the total of the weights.

Deep learning methods have multiple levels of representation, at an increasingly abstract level. The further you progress in ›

FIG. 2: A typical CNN age estimation system. An age estimation system follows a general process that includes face detection, landmark detection and face alignment, features extraction and the classification itself.

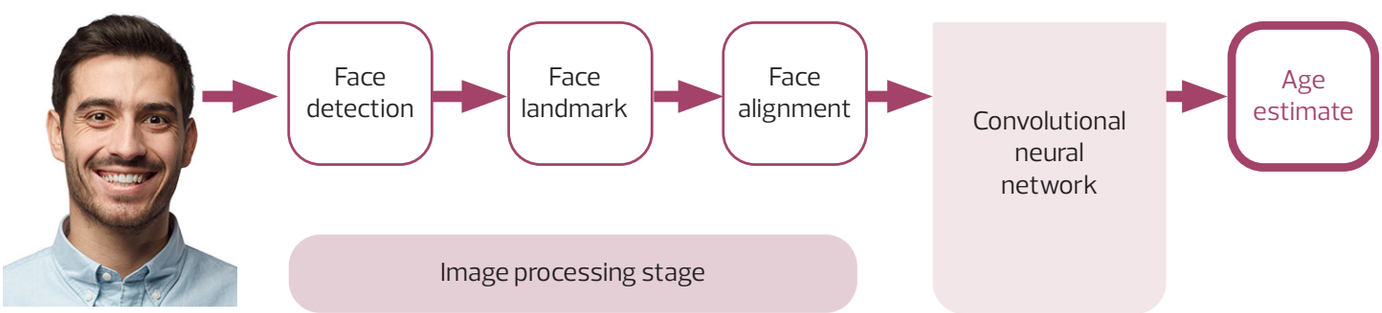


FIG 2: A typical Artificial Neural Network with a Regression Example. The index of the highest probability value is the output.

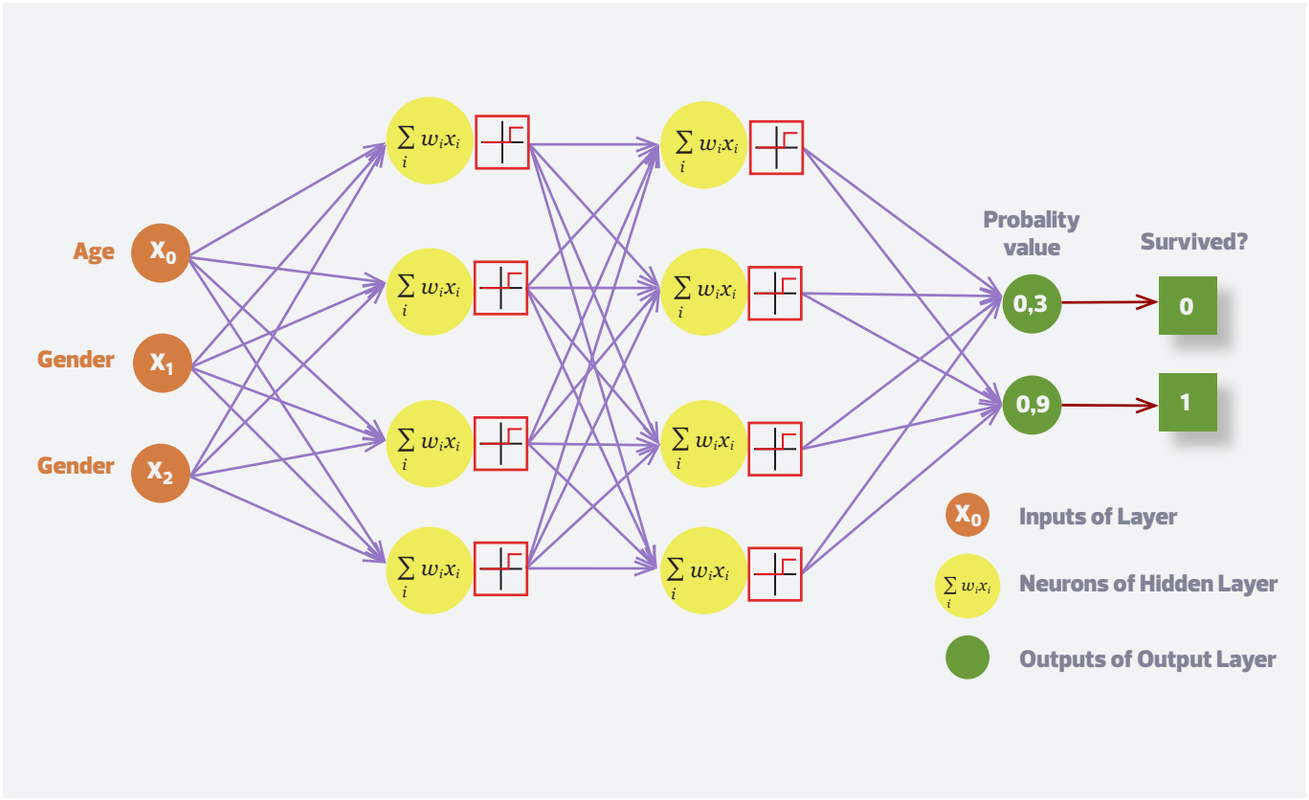


TABLE 3: MAE and RMSE for all methods. Best performance is indicated in bold font.

Method	MAE	RMSE
Radiology	**1.3740**	**1.6647**
AI (free)	2.7329	3.6482
AI (Commercial)	2.5510	3.3179

TABLE 4: Accuracy, precision, recall and F1-score for identifying a miner for all methods. Best performance is indicated in bold font.

Method	accuracy	precision	recall	F1-score
Radiology	**0.8269**	**0.8750**	**0.7778**	**0.8235**
AI (free)	0.6346	1.0000	0.2963	0.4571
AI (Commercial)	0.7885	0.7667	0.8519	0.8070

› the network, the more complex the features the neurons can recognize, as they aggregate features from the previous layer.

To learn, a neural network must do more than just send signals through its layers of neurons. It also needs a way to see if the correct result was given. If not, a signal must be sent back so that all neurons can tune their activations to improve the results. In this process, the network learns to recognize correlations between certain relevant functions and optimal results.

While the network is being trained, there is a good chance that it will come up with wrong answers. It must see hundreds of thousands, even millions, of images until the weights are so finely tuned that it almost always gives the right answer. It is at that moment that the neural network has learned what the age could be.

The success of the result depends entirely on the programmer's ability to accurately define an "age" feature set.

The advantage of deep learning is that the program builds the feature set itself, without supervision. Not only is this faster, but it is usually more accurate. The program uses the information in the training data to create an "age" feature set and build a predictive model.

The program simply looks for patterns in the data. With each iteration, the predictive model that the computer creates becomes more complex and accurate.

Statistical Analysis

The age estimate is evaluated through the mean absolute error (MAE) and the root mean square error (RMSE). Both metrics quantify how precise a prediction is (with lower values indicating better performance, and zero indicating a perfect prediction). The RSME gives more importance to large deviations from the actual value because of the squared differences. The values can be found in **table 3**.

To assess the equality between the methods, the prediction errors were analyzed using a repeated measures ANOVA procedure. This analysis showed differences in age errors across the three estimation methods ($F(2, 102)$, $p<0.001$, $\eta^2 = 0.189$). Moderate differences occurred between the radiology method and the commercial AI program ($p<0.001$, $d=0.797$), and large differences between the commercial program and the free AI program ($p<0.001$, $d=0.930$). No difference was observed between radiology and the commercial program ($p=0.37$). This analysis was done with R v4.3.2 (using the rstatix package).

To assess the performance of correctly identifying an individual as a minor, the problem was considered as a binary classification problem, with a minor as the positive class. A subject is considered a minor if the (estimated) age is below 18 years. The performance was evaluated using accuracy, precision, recall and the F1-score. Table 4X gives an overview of these metrics. The radiological method offers the best performance (F1-score of 0.82), followed by the commercial AI program (F1-score of 0.81), and finally the free AI program (F1-score of 0.46).

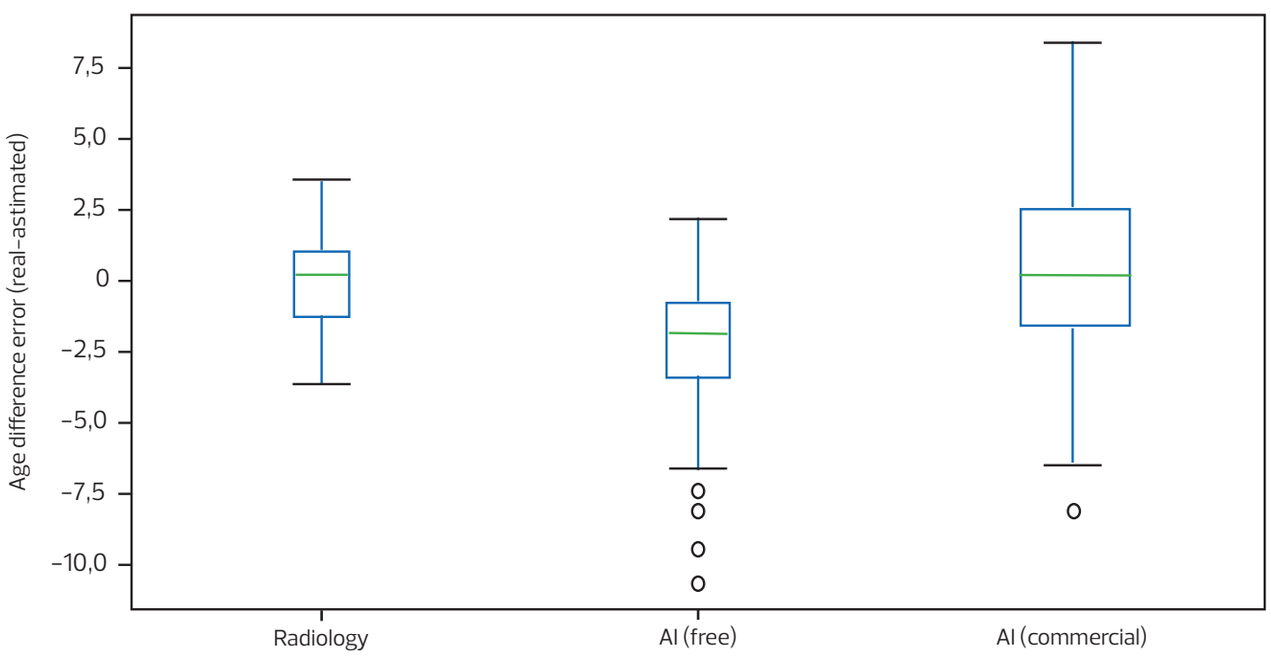
TABLE 5: Age and Gender classification. Accuracy if the subject is younger or older than 18 years.

Method	Age classification	Gender classification
Radiologic method	82.69 %	-
AI free	80.72 %	100 %
AI commercial program	81.93 %	100 %

RESULTS

Results are shown in Tables 3-5 and figure 3. The chronological mean age of all participants was 19.88 years. From 83 radiographs, only 52 could be used because 20 individuals had no or too few wisdom teeth and an additional 11 participants are ›

Figure 4: Boxplot of the errors for the estimate age for the three methods.



› excluded because the difference between the chronological and estimated age becomes increasingly greater with the used method of the Belgian Army. For the AI programs, all photos could be used.

The radiological method yielded a mean absolute age error (MAE) of 1.37 years and a root mean squared error (RMSE) of 1.67 years. The commercial AI program yielded an MAE of 2.55 years and a RMSE of 3.32 years. The free AI program yielded a MAE of 2.73 years and a RMSE of 3.64 years.

A repeated measures ANOVA showed differences of age errors across the three estimation methods ($F(2,102)$, $p<0.001$, $\eta^2=0.189$). Moderate differences occurred between the radiological method and the commercial AI program ($p<0.001$, $d=0.797$), and large differences between the commercial program and the free AI program ($p<0.001$, $d=0.930$). No difference was observed between the radiological and the commercial AI program ($p=0.37$).

Regarding the problem of correctly identifying an individual as a minor, the radiological method offers the best performance (F1-score of 0.82), followed by the commercial AI program (F1-score of 0.81), and finally the free AI program (F1-score of 0.46).

The radiological method appears to be the most performant method when considering age prediction. The same also holds when considering the classification performance.

Both AI program scores 100% in determining gender *(Tab. 5)*.

DISCUSSION

The generation of Automatic Age Estimation (AAE) has emerged in recent years as a result of the rapid development of the AI industry.

The AI models are created by experts in computer vision, and the majority of them were developed using open-source internet data sets, which are certainly not the optimal option for forensic applications.

There are two important steps in training a successful age-estimation model: the selection of the face data set and the determination of the algorithm logic. Numerous face datasets have been employed for AAE training, including APPA-REAL and others like Morph, FG-NET data sets (12). Taking the classical Morph dataset as an example, European and American populations account for the vast majority of the data, whereas Asian populations only account for 0.28%. This is also a shortcoming in our study because the ultimate goal in our study was to estimate the age of refugees being screened in the military hospital. Most of the refugees come from Africa or the Middle East and until now we did not find a database with such faces.

The limitations of this study are as follows: although deep learning is a powerful technique, there have not been significant advancements in its interpretability, which has been a barrier to the continued growth of this field. AI should provide not only accurate prediction results but also insights into the algorithm's logic and thought process. We expect that in the future, more doctors will focus on algorithms' underlying logic and interpretability, closely collaborate with experts in AI, and employ advanced AI technology to alter current evaluation systems. This will pave the way for the utilization of Big Data in forensic dentistry, which is a significant challenge, especially in Europe, for putting these large, high-quality datasets together so that we can actually train and use models that are suited for our population.

CONCLUSION

The radiological method is still more reliable and stable to estimate the age. However, is the Artificial Intelligence software today is a reliable and useful alternative when subjects are missing wisdom teeth.

The difference between chronological age and estimated age will still be a problem in accuracy. Both systems have their shortfalls and even when we need to determine the correct age whether the individual is younger or older than 18, there is still a small non acceptable margin in both methods of error in estimating age.

To our knowledge, unlike the relatively mature state of research for predicting the chronological age of a face, the research for predicting apparent and/or chronological age is still in its infancy. Building an apparent age database from different genders, different ethnicity, different age group in a range between 15 and 21 years and different social backgrounds and dealing with ethical issues, stil requires the collection of subjective opinions from a number of observers and data integration.

Conflict of Interest:
The authors declare no conflict of interest.

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From left to right: Pablo Valientes Samalea, Matthias Neukermans, Tom Verhofstadt.



Bart De Clerck

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• Scientific articles, analyses or reviews of books and articles related to military medicine, symposia or congress proceedings, scientific events and announcements written in French and English will be considered for review.

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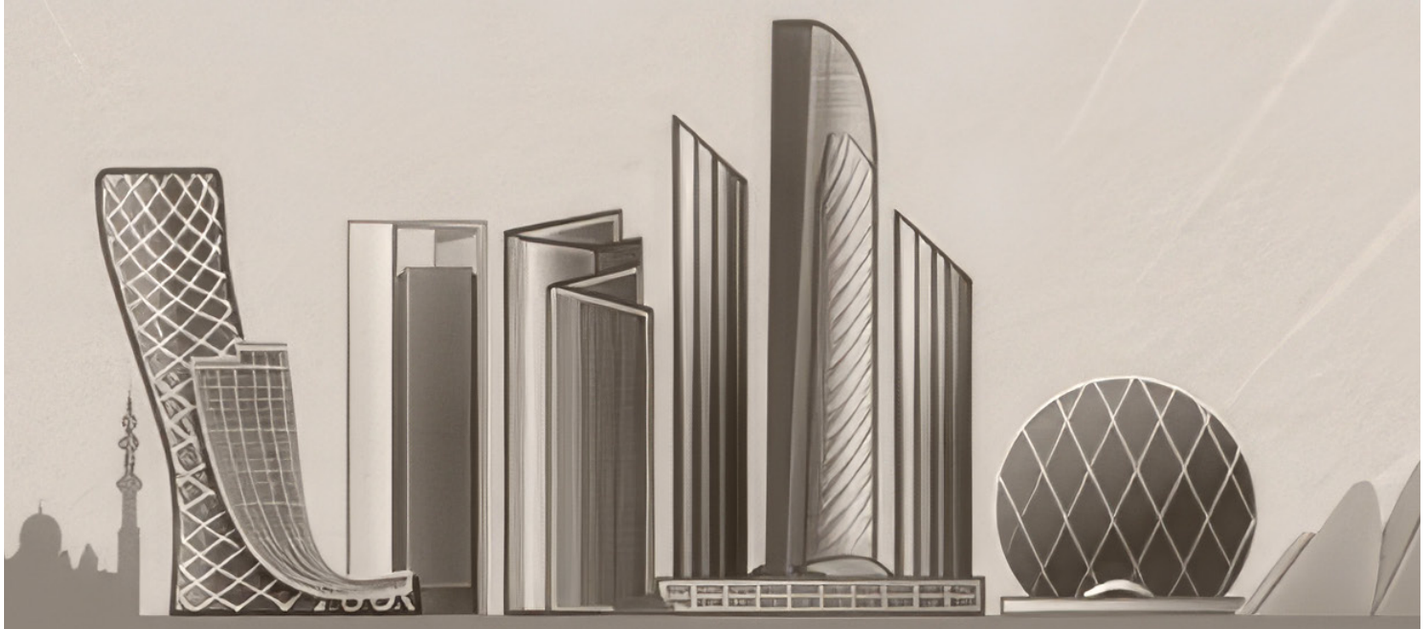

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