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Modern Sterilization Standards in the Beauty Industry: The Role of Next-Generation Autoclaves

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ABSTRACT

Against the background of the exponential dynamics of the global market for aesthetic services, estimated at 5–7% annually, and the parallel expansion of the pool of practicing professionals, the issue of infection safety is moving to the forefront. Within the study, an analysis of current sterilization standards in the beauty sector was conducted with an emphasis on the functional and regulatory advantages of new-generation autoclaves. The objective of the study is to scientifically substantiate the necessity of the widespread implementation of class B autoclaves, compliant with the European standard EN 13060, as a mandatory technological foundation for all invasive and potentially invasive procedures. The methodological framework of the study includes a systematic review of the scientific literature on epidemiological risks in cosmetology, a content analysis of regulatory and technical documents, and the interpretation of industry reports. The results obtained demonstrate that traditional approaches to disinfection and sterilization, including the use of class N autoclaves, do not provide a sufficient level of biosafety when processing complex instruments (burs, device handpieces, hollow instruments). Such insufficiency creates significant prerequisites for the transmission of bloodborne infections, including viral hepatitis B and C, as well as bacterial infections caused by Mycobacterium fortuitum and Staphylococcus aureus. The study proposes an adaptation of the medical Spalding risk classification to the nomenclature of instruments used in the beauty industry and argues for the technological superiority of class B autoclaves, which employ fractionated pre-vacuum technology, ensuring complete steam penetration into hard-to-reach cavities and channels. It is concluded that the implementation of class B autoclaves constitutes not only an effective measure for protecting public health, but also a strategic competitive advantage responding to the growing consumer demand for demonstrable safety and high quality of services. The material is addressed to practicing professionals, salon owners, representatives of regulatory authorities, and researchers in the field of public health.

KEYWORDS: *sterilization, class B autoclave, Infection Control, Beauty Industry, En 13060 Standard, Patient Safety, Spalding Classification, Bloodborne Infections, Mycobacterium Fortuitum, Professional Standards.*

Introduction

The global beauty industry is undergoing a phase of rapid expansion. According to analytical estimates, the volume of the global market for aesthetic services will reach 677,19 billion by 2025, with the expected compound annual growth rate (CAGR) remaining in the 5–7% range through 2030 [1]. The economic dynamics are accompanied by employment growth: according to the US Bureau of Labor Statistics, in 2023–2033 the number of jobs for manicurists and pedicurists will increase by 11,8%, which significantly outpaces the average growth rate for the economy as a whole [4]. At the same time, such rapid expansion, relying on a high share of self-employed workers and small enterprises, exposes a systemic gap: the development and implementation of unified, evidence-based safety and infection-control standards lag behind the pace of growth in the industry [5].

Against this backdrop, the relevance of infection risks inherent to a range of cosmetology interventions increases. Organizations providing personal services have repeatedly been identified as foci of infection spread. Illustrative are outbreaks of furunculosis caused by Mycobacterium fortuitum, linked to contaminated pedicure footbaths. In one episode, the number of affected clients exceeded one hundred [7]. Systematic reviews and meta-analyses show a statistically significant association between tattooing and the risk of transmission of hepatitis C virus (HCV), with a pooled odds ratio of 2,79. By various estimates, bacterial

complications are noted in 0,5–6% of clients after tattooing, often caused by Staphylococcus aureus, including methicillin-resistant strains (MRSA) [10, 11]; the spectrum of threats is further complemented by transmission of hepatitis B virus (HBV) and fungal infections [12].

At the same time, modern aesthetic procedures are becoming more complex and potentially more invasive. Work by specialists with hard materials for nail extensions involves the use of high-speed devices and burs, which is associated with microtrauma, abrasions, and accidental breaches of skin integrity. As a result, the likelihood of direct contact of instruments with blood and other biological fluids increases, and a routine manipulation turns into a situation with a real threat of blood-borne transmission of pathogens.

Thus, a significant scientific gap is revealed between the rigorous, evidence-based standards of infection control operating in medicine [14] and the often fragmentary, insufficiently regulated practices in the beauty sector. Studies indicate a complex set of barriers to the implementation of adequate safety measures: insufficient staff training, low adherence to protocols, and the absence of a regulatory framework adapted to nonmedical organizations [15].

The scientific novelty of the study lies in a targeted synthesis that directly connects the documented public health risks in the beauty industry with a specific technological solution — class B autoclaves, — and justifies their necessity by transferring the fundamental principles of medical risk classification into the sectoral context.

The author's hypothesis is that the implementation of class B steam sterilizers (autoclaves) compliant with the European standard EN 13060 represents not merely a process improvement, but a necessary and non-substitutable condition for contemporary providers of aesthetic services, with the aim of reliably reducing the risks of transmission of bacterial and viral pathogens and aligning industry practices with current expectations in public health.

The aim of the study is to substantiate scientifically the necessity of universal implementation of class B autoclaves compliant with the European standard EN 13060 as the mandatory technological foundation for all invasive and potentially invasive procedures.

Materials and Methods

In the corpus of sources, four complementary strands can be traced: the market and workforce framework of the beauty industry, empirical data on infectious risks, the assessment of infection control technologies/procedures, and the regulatory context; in each of them the authors converge on the point that a sustained reduction of risk is possible only with a transition to validated sterilization of reusable instruments (including next-generation autoclaves with cycle traceability), integrated into a multi-level asepsis assurance system.

In the area of market and workforce dynamics, DemandSage [1] aggregates statistics and points to the scale and diversification of the global beauty market, setting the economic background in which procedure safety becomes an element of the value proposition. McKinsey & Company [2; 3] develops an industry outlook, recording a segmental shift in demand and rising operational pressure on chains, which strengthens requirements for process standardization of sterilization and for digital traceability. The U.S. Bureau of Labor Statistics [4–6] shows sustained employment growth in the skin-care and personal services segments, indicating an expansion of contact-intensive practices and, consequently, the scaling of infectious risks that require reproducible sterilization regimes. Deloitte [15] complements the picture with consumer-sector macrotrends (price sensitivity, production discipline, risk management in supply chains), arguing for technologically mature sterilization solutions with in-line quality control.

Empirical evidence of risks in beauty services underscores the role of water systems and skin microtraumas as key nodes of pathogen transmission. Winthrop K. L. et al. [7] describes an outbreak of folliculitis associated with pedicure baths, which became a turning case for reassessing salons' engineering and sanitary nodes. Vugia D. J. et al. [8] confirms the presence of nontuberculous mycobacteria in whirlpool footbaths and points to design and operational factors as reservoirs of contamination. Vanhooteghem O., Theate I., De Schaetzen V. [9] demonstrate a clinical case of periungual Mycobacterium marinum infection after fish manicure, expanding the spectrum of risk-bearing procedures. Dieckmann R. et al. [10] in a systematic review summarizes bacterial complications and emphasizes the importance of material quality and instrument sterility. Taken together, these works set out a risk mechanism that is addressed not so much by surface disinfection as by full sterilization with validated cycles for porous and hollow loads.

Assessments and validation of infection control technologies/procedures converge on prioritizing steam sterilization over surrogates. Humphreys P. N., Davies C. S., Rout S. [11] experimentally show that UV chambers reduce airborne contamination of premises but do not

ensure sterility of already contaminated instruments, creating a risk of false safety and substituting disinfection for sterilization. Khan S. et al. [14] reconceptualize elements of asepsis in dermatologic practice, emphasizing a systems approach: skin preparation, barrier means, instrument handling, verification of sterilization cycles, and documentation, thereby supporting the inclusion of autoclaving in a continuous chain of barriers with mandatory process indicators and traceability.

The regulatory-policy perspective records mosaic requirements and gaps in the evidence base. Yang J. et al. [12] compare the risks of HBV/HCV transmission in U.S. salons with the heterogeneity of state requirements, noting a frequent bias toward disinfection instead of mandatory sterilization for high-risk manipulations. Popalyar A. et al. [13] identify fragmented norms, deficits in training and inspection, substantiating the need to unify standards and quality control tools (including Bowie–Dick, process and biological indicators, as well as cycle logging).

The final comparison of approaches shows a coherent logic: epidemiology and clinical evidence [7-10] shape the picture of risks; technological and practice-oriented reviews [11, 14] determine the suitability of control methods; market and workforce data [1-6; 15] define the scale and requirements for reproducibility; regulatory studies [12, 13] reveal institutional constraints. Within this frame, the role of next-generation autoclaves is to ensure validated cycles for typical loads of beauty practices and digital traceability under conditions of growing throughput and a heterogeneous regulatory environment.

As for existing contradictions and gaps, the following should be noted: first, market assessments differ in coverage and methodology, which complicates the direct extrapolation of the scale of risk to the economics of sterilization programs. Second, evidence on parenterally transmitted viruses in salons remains heterogeneous against the backdrop of a more convincing base on NTM/bacterial complications. Third, surrogate technologies (UV cabinets) are methodologically discredited as a replacement for sterilization, but publications lack field data on the operation of specific classes of autoclaves in the beauty environment (mixed loads, packaging, short/incomplete cycles, human factors) and on their economic-environmental profile; the digital traceability of cycles and its impact on compliance are also weakly covered. These issues set the agenda for empirical validation of next-generation autoclaves in real salon workflows with mandatory documentation of outcomes and costs.

Results and Discussion

The fundamental pillar of infection control systems is the Spaulding classification, which stratifies medical instruments into three groups according to the level of risk of infection transmission during their use. Despite its clinical origin, this system has substantial potential for careful adaptation and implementation in the beauty industry, where the probability of breaching the integrity of the skin and mucous membranes is high [14]. The classification provides for:

- Critical instruments: those interacting with sterile tissues or the vascular system. Any degree of contamination here entails the maximal risk of infection.

- Semicritical instruments: those contacting intact mucous membranes or already disrupted skin. The minimal processing standard is high-level disinfection (DVU).

- Noncritical instruments: those contacting only intact skin that maintains a barrier function. Low- or intermediate-level disinfection is sufficient for them.

The key failure of infection control in beauty practices is not the absence of processing per se, but a systematic error in risk assessment and category assignment. Instruments such as cuticle nippers, scrapers, burs for hardware manicure, and tweezers for eyebrow correction are often erroneously classified as semicritical and limited to chemical disinfection with solutions that are effective against vegetative bacterial forms but insufficient against spores, mycobacteria, and some viruses. However, at the moment when such an instrument causes microbleeding or is used on already damaged skin (for example, when removing a hangnail), it de facto shifts into the critical category. It is precisely this dynamic shift in risk status during the procedure that remains unaccounted for and becomes the primary cause of a significant share of preventable infections [3, 6, 9].

A practical conclusion follows from this: to ensure client safety, any reusable instrument that by design or by its typical technique of application has a high probability of breaching the skin barrier should be presumed critical and subjected to mandatory sterilization. Such a preventive approach reduces dependence on the human factor and random incidents during work. In Table 1, an adapted matrix of instrument classification intended for everyday use by industry professionals is presented.

Table 1. Classification matrix of instruments in the beauty industry and the required level of reprocessing (compiled by the author based on [13, 14]).

Type of instrument	Examples of procedures	Primary risk	Spaulding classification	Required level of reprocessing
Manicure/pedicure instruments (nail nippers, scissors, scrapers)	Manicure, pedicure, cuticle removal	Contact with blood, broken skin	Critical	Sterilization
Bits (diamond, carbide, ceramic)	Electric manicure/pedicure, nail correction	Microtrauma, abrasions, contact with blood	Critical	Sterilization
Needles for permanent makeup, microblading blades	Permanent makeup, tattooing	Penetration into the dermal layer, contact with blood	Critical (single-use)	Sterilization (industrial)
Tweezers, comedone extractors	Brow shaping, facial cleansing	Contact with broken skin, purulent contents	From semicritical to critical	Sterilization
Microdermabrasion tips	Mechanical peeling	Contact with broken skin	Semicritical	High-level disinfection / Sterilization
Pedicure bath basin	Pedicure	Contact with intact skin	Noncritical	Low/intermediate-level disinfection

Recognizing that a wide range of instruments requires sterilization, the next logical step is the selection of a technologically appropriate method. The key regulatory standard for small steam sterilizers (with a chamber volume up to 60 liters) is EN 13060, which defines their functional capabilities and introduces three classes of sterilization cycles directly corresponding to the types of loaded items [7, 8].

Class N: intended exclusively for unpackaged, solid (monolithic) instruments without internal cavities and channels. The cycle operates on gravity displacement of air by steam: the lighter steam is supplied from above and displaces the cold air downward through the exhaust valve.

Class S: designed for sterilization of those items specified by the manufacturer of the particular autoclave. This is an intermediate category with variable capabilities: certain models have pre-vacuum and drying; however, the suitability of such modes must be confirmed for the specified load types.

Class B: applicable to any medical items — porous, hollow (including dental turbine handpieces and manicure devices), packaged and unpackaged, solid and textile materials. These autoclaves are universal and provide the highest reliability of the process.

The technological advantage of class B is determined by the presence of a powerful vacuum pump that implements a phase of fractionated pre-vacuum. Before steam admission, the pump repeatedly (usually three times) evacuates air from the chamber, creating a deep vacuum. This makes it possible to remove over 99 % of the air not only from the chamber volume but, critically, from the internal channels and cavities of the processed items [2, 13, 15]. Air pockets, inevitable with the gravity method (class N), hinder contact of saturated steam with the surface and render the process ineffective. Only complete removal of air guarantees penetration of steam to every point and inactivation of all microorganisms, including spore forms.

In addition, class B autoclaves apply vacuum at the final stage — for vacuum drying. After sterilization and pressure release, the pump again creates a vacuum, which ensures intensive evaporation of moisture from surfaces even at a comparatively low temperature. The instruments are removed completely dry, which prevents recontamination and corrosive damage. The diagram of the operating cycle of a class B autoclave is shown in Figure 1.

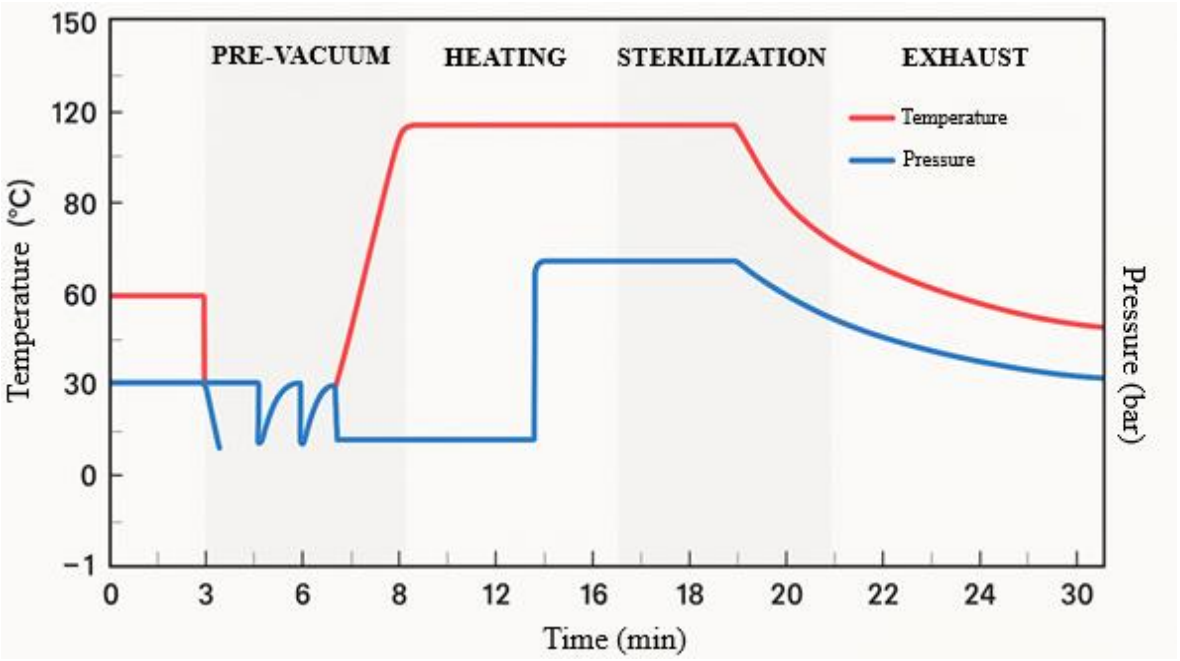


Fig. 1. Graphic diagram of the operating cycle of a class B autoclave (compiled by the author based on [2, 13, 15]).

In the beauty industry, where instruments of complex configuration and hollow construction are increasingly used (including manicure device handpieces), the use of class N autoclaves does not ensure verifiable sterility. The required level of microbiological safety, comparable to medical standards, is achievable only when using class B autoclaves.

Analysis of documented infection outbreaks clearly demonstrates the consequences of noncompliance with adequate sterilization regimes. An outbreak of furunculosis caused by M. fortuitum was traced to biofilms formed within the recirculating systems of pedicure tubs — in areas inherently inaccessible to routine surface disinfection [7, 8]. Although the tubs themselves are not amenable to autoclaving, this example underscores the necessity of mandatory sterilization of all reusable instruments (nippers, burs, files), which constitute a critical control point in service delivery. Similarly, the elevated prevalence of HCV among individuals with tattoos directly indicates risks associated with the reuse of needles or holders without effective steam sterilization capable of treating their internal channels. Only class B autoclaves can accomplish this [10]. Table 2 summarizes key pathogens and their associations with procedures in the beauty industry.

Table 2. Summary table of pathogens associated with services in the beauty industry (compiled by the author based on [7, 8, 10]).

Pathogen	Associated services	Transmission vector	Control failure	Recommended measure
Mycobacterium fortuitum	Pedicure	Biofilms in whirlpool systems, contaminated instruments	Inadequate equipment disinfection	Protocols for system cleaning; Sterilization of all reusable instruments in a class B autoclave
Hepatitis C virus (HCV)	Tattooing, piercing, manicure	Contaminated needles, holders, instruments	Reuse of single-use items; Ineffective sterilization (air pockets)	Use of single-use needles; Sterilization of holders and instruments in a class B autoclave
Hepatitis B virus (HBV)	Tattooing, piercing,	Contaminated instruments	Ineffective sterilization	Personnel vaccination; Sterilization of all instruments in a class B

	manicure			autoclave
Staphylococcus aureus (including MRSA)	All invasive procedures	Contaminated instruments, surfaces, staff hands	Noncompliance with hand hygiene; Inadequate disinfection/sterilization	Sterilization of all critical and semicritical instruments in a class B autoclave
Dermatophytes (fungi)	Pedicure, manicure	Contaminated instruments (files, burs), surfaces	Inadequate disinfection	Sterilization of all metal instruments; Use of single-use files

Despite their indisputable necessity, the universal adoption of high sterilization standards is impeded by a set of systemic barriers: capital-intensive upfront investments in equipment, a deficit of professional knowledge and skills among personnel, insufficiently stringent regulatory control and monitoring, and an entrenched notion of the excessiveness of medical requirements for the beauty industry [15].

Nevertheless, current market trends provide a substantial counterargument to the cost-based objection. Consumers are becoming information-savvy, critically assess advertising claims, and orient themselves toward verifiable real value and the effectiveness of services [2]. This opens a strategic vector for rethinking the category of value, which includes an integral component: demonstrable safety. A salon that invests in a class B autoclave and establishes transparent client-information practices (for example, opening sterile kraft packages with indicators immediately before the procedure) does not merely incur costs: it constructs a durable competitive advantage, strengthens trust, and legitimizes a higher service price. As a result, the public health imperative converges with the logic of rational business strategy: investments in safety are transformed into investments in reputational capital and customer loyalty.

Conclusion

The conducted analysis demonstrates that the combination of factors — the rapid expansion of the beauty industry, the increasing technical complexity and invasiveness of procedures, and the documented epidemiological risks — objectively raises the bar for infection safety requirements. Approaches previously considered sufficient do not provide reliable protection under current conditions, neither for clients nor for professionals.

The key results can be summarized as follows. The foundational tenets of infection control formulated for clinical practice, including the Spalding risk classification, are fully relevant to the beauty industry. The predominant sources of incidents remain the disregard of these principles and the erroneous assignment of instruments to noncritical or semicritical categories. The technological capabilities of sterilization equipment directly determine the attainable level of safety: aligning the requirements of EN 13060 with the physical principles of steam sterilizers shows that only class B autoclaves with fractionated pre-vacuum and vacuum drying can guarantee the sterility of complex, hollow, and packaged items characteristic of modern cosmetology interventions. At the same time, the implementation of such systems should not be interpreted as an exclusively costly measure: in a saturated market where the value of quality, transparency, and safety is increasing, investment in hospital-grade equipment becomes a weighty marketing argument and a durable competitive advantage that builds audience loyalty and reputational capital.

Consequently, the stated goal — to provide a scientific rationale for the role of class B autoclaves as the gold standard — has been achieved by demonstrating their technological superiority and the inevitability of their selection arising from risk analysis. The author's hypothesis regarding the nonalternativeness of their implementation for the modern sector has been confirmed.

The practical significance of the work lies in proposing a clear, evidence-based trajectory for all market participants. For practitioners and business owners, it is a guide to risk reduction and a tool for strategically sustainable development. For regulators, it serves as a scientific basis for updating and tightening licensing requirements and inspection protocols. For consumers, it provides improved awareness and the ability to make informed choices of safe services. The transition to new sterilization standards is not an option but a necessary condition for the formation of a

civilized, responsible, and safe market for aesthetic services.

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