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Localized Cancer Therapy: A Review on Transdermal and Implantable Anticancer Patches

Jadhav Aniket Babasaheb[1], Shinde Om Bhausaheb[2], Attar Jahid Mobin[3], Bhise Nilam Dilip[4], Deshmukh D. B[5], Unde R. S[6]
Mrs. Saraswati Wani College of D Pharmacy, Ganegaon, Rahuri, Ahliyanagar[1,2,3,4]
Mrs. Saraswati Wani College of D Pharmacy, Ganegaon, Rahuri, Ahliyanagar[5,6]

Abstract: *Localized anticancer patches are being investigated as drug-delivery platforms that may concentrate therapeutic agents at accessible tumors while limiting exposure of healthy tissues. Approaches discussed in this review include conventional topical patches, drug-in-adhesive and matrix systems, hydrogel reservoirs, dissolving microneedles, nanoparticle-enabled formulations, and implantable microneedle systems. Candidate materials include hyaluronic acid, polyvinyl alcohol, polyvinylpyrrolidone, sodium alginate, chitosan, hydroxypropyl methylcellulose, ethyl cellulose, and adhesive polymers. Investigated payloads include 5-fluorouracil, doxorubicin, cisplatin, methotrexate, tamoxifen, natural-product extracts, and immunomodulators. Functional nanomaterials may provide additional capabilities such as controlled release, magnetic targeting, photothermal effects, or stimulus-responsive activation. It depends on safety, effectiveness and etc. Many advanced concepts remain at the preclinical or formulation-development stage, and clinical benefit should not be assumed without robust evidence. This review summarizes the principal patch designs, materials, payloads, potential advantages, limitations, and research priorities for localized cancer therapy. [1,2,4,7,12]..*

Keywords: anticancer patch; transdermal drug delivery; microneedles; localized therapy; polymeric matrix; nanocarriers; skin cancer

I. INTRODUCTION

Cancer treatment may involve surgery, radiotherapy, systemic medicines, topical medicines, or combinations selected according to tumor type and stage. Systemic chemotherapy can expose healthy tissues to cytotoxic drugs, whereas topical delivery is limited by the barrier function of the stratum corneum and by the depth and location of the lesion. Localized patches are being explored to improve drug residence at accessible lesions and to control the rate and location of drug release. [1,3,4]

Microneedle patches use arrays of microscopic projections to cross the stratum corneum and deposit a formulation into superficial skin layers. Depending on their length, composition, and design, microneedles may be solid, coated, dissolving, hollow, or hydrogel-forming. They are generally described as minimally invasive rather than universally painless or entirely bloodless; tolerability and tissue effects depend on device design and application. [2,4,12,15]

The aim of this review is to summarize the materials, active agents, formulation architectures, and emerging technologies described for localized anticancer patches, while identifying key limitations that must be addressed before clinical translation. [1,2,4,7,12]

II. REVIEW APPROACH

This article is structured as a narrative review based on the references supplied in the source document. A reproducible systematic search strategy, database list, search dates, screening criteria, and risk-of-bias assessment were not provided. Therefore, the article should not be presented as a systematic review. [1–15]

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III. PATCH PLATFORMS AND MATERIALS

3.1 Polymer matrices and hydrogel-forming materials

Polymer selection affects mechanical strength, drug loading, swelling, adhesion, degradation, and release kinetics. The source document identifies hyaluronic acid, polyvinyl alcohol (PVA), polyvinylpyrrolidone (PVP), sodium alginate, gelatin meth acryloyl (GelMA), hydroxypropyl methylcellulose (HPMC), ethyl cellulose (EC), chitosan, and Carbopol as formulation materials. Their suitability depends on the intended device, drug compatibility, route of administration, and required release profile. [4,14]

3.2 Backing layers and adhesives

These layer helps for the binding of the drugs and provide better action to the skin. Materials mentioned in the source include ethylene-vinyl acetate (EVA), acrylic adhesives, silicone adhesives, polyisobutylene (PIB), polyurethane, and poly (propylene fumarate) (PPF). Selection requires assessment of skin compatibility, adhesion during wear, residual drug, extractables/leachable, and removal characteristics. [1,7,14]

3.3 Plasticizers and formulation aids

Glycerol and polyethylene glycol 400 (PEG 400) are listed as plasticizers or formulation aids. Their concentration can affect flexibility, moisture uptake, mechanical integrity, and drug diffusion. Compatibility and stability testing are needed because excipients can alter both patch performance and skin tolerability. [14]

3.4 Drug-in-adhesive and matrix-type patches

In a drug-in-adhesive system, the active ingredient is incorporated into a pressure-sensitive adhesive that also secures the patch to the skin. In a matrix-type system, the drug is dispersed or dissolved in a polymer matrix and diffuses from the matrix toward the application site; a separate adhesive may be used. EC, HPMC, PVP, Eudragit polymers, EVA, and polyurethane are among the polymers identified in the source. These architectures are established drug-delivery concepts, but their suitability for a particular anticancer agent must be demonstrated experimentally. [1,7,14]

IV. ACTIVE AGENTS AND THERAPEUTIC PAYLOADS

4.1 Conventional anticancer agents

The source document identifies 5-fluorouracil (5-FU), doxorubicin, cisplatin, methotrexate, and tamoxifen as candidate payloads. Topical 5-FU has relevance to selected superficial non-melanoma skin lesions; its use and effectiveness depend on the specific diagnosis and approved clinical guidance. Doxorubicin, cisplatin, methotrexate, and tamoxifen have different pharmacological properties and are not interchangeable. Their incorporation into a patch requires evidence of adequate local exposure, stability, controlled release, and acceptable local and systemic toxicity. [1,7,8,13]

4.2 Natural products and plant-derived materials

Curcumin, Usnea Barbata extract, and materials derived from banana peels are mentioned in the source. Natural products may be investigated as active compounds or as reagents for nanoparticle synthesis, but these roles should be clearly distinguished. Evidence of in-vitro activity or successful nanoparticle synthesis does not by itself establish clinical anticancer efficacy, dose suitability, or safety for transdermal use. [9–11]

4.3 Immunomodulators and biologics

Interleukin-2 (IL-2) and the cyclic dinucleotide 2′3′-cGAMP are described as payloads for implantable or microneedle-based cancer-immunotherapy approaches. Such systems aim to deliver immunostimulatory signals locally. Their performance requires evaluation of biological activity after formulation, release kinetics, immune effects, local inflammation, and systemic exposure. [12]

V. NANOMATERIALS AND STIMULUS-RESPONSIVE SYSTEMS

The source identifies iron oxide nanoparticles, titanium dioxide nanosheets, palladium nanoparticles, graphene oxide quantum dots, and silver or gold nanoparticles as materials under investigation for targeting, catalytic activation, photothermal effects, or reactive oxygen species generation. Liposomes are also listed as nanocarriers. These materials

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have distinct physicochemical and biological properties; they should not be treated as a single interchangeable class. [2,6,8,11,12]

Photothermal approaches use light-absorbing materials to convert incident light into heat, potentially combining local heating with drug delivery. Stimulus-responsive systems may be designed to release or activate a payload in response to light, temperature, pH, enzymes, or other cues. Claims about selective tumor-cell killing, ferroptosis, proptosis, or immune activation must be linked to direct experimental evidence and should not be generalized to all patch systems. [2,6,8,12]

Important translational questions include nanoparticle distribution and clearance, degradation products, batch-to-batch reproducibility, local tissue injury, long-term toxicity, light penetration, device usability, and manufacturing controls. [2,4,6,8,12]

VI. POTENTIAL ADVANTAGES AND CURRENT LIMITATIONS

6.1 Potential advantages

Local drug deposition may increase exposure at an accessible lesion while reducing—but not necessarily eliminating—systemic exposure. [1,7,8]

Controlled-release matrices may prolong residence and reduce the need for frequent application, depending on formulation performance. [1,7,14]

Microneedles can improve delivery across the stratum corneum compared with passive topical formulations. [2,4,12,15]

Patch-based delivery may offer practical advantages in administration and adherence for selected indications. [1,4,7]

6.2 Limitations and safety considerations

Passive transdermal delivery is unsuitable for many large, hydrophilic, or potent anticancer molecules without an appropriate delivery strategy. [1,4,7]

The depth and accessibility of a tumor determine whether a skin-applied patch can deliver a therapeutically relevant dose. [1,2,7,12]

Skin irritation, sensitization, infection risk, pain, local tissue damage, and unintended systemic exposure require evaluation. [1,2,4,7,12]

Microneedle mechanical strength, insertion consistency, dose uniformity, sterility where required, and storage stability are critical quality attributes. [2,4,12,15]

Many advanced designs are still in the early research phase; results from lab studies should not be considered proven clinical benefits. [1,2,4,12]

Scale-up, regulatory classification, reproducible manufacturing, packaging, and long-term safety remain important barriers. [1,2,4,12,14]

VII. FUTURE PERSPECTIVES

Future research should prioritize well-characterized formulations with clear target indications, clinically relevant models, validated analytical methods, and appropriate comparators. Studies should report drug loading, content uniformity, mechanical properties, insertion or deposition performance, in-vitro release, skin permeation, local retention, systemic pharmacokinetics, stability, and toxicity. Where nanoparticles or light-responsive systems are used, investigators should also characterize particle size distribution, morphology, surface chemistry, degradation, and stimulus-dependent performance. [1,2,4,7,12,14]

Translation will require reproducible manufacturing, quality-by-design approaches, scale-up studies, biocompatibility evaluation, and regulatory planning. Clinical claims should be based on appropriately designed human studies rather than inferred from formulation novelty alone. [1,2,4,12,14]

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VIII. CONCLUSION

Transdermal, microneedle, hydrogel, and implantable patch platforms offer promising research routes for localized delivery of selected anticancer agents. Polymer matrices, adhesive systems, nanocarriers, and stimulus-responsive materials may be tailored to improve drug retention and release at accessible lesions. Nevertheless, benefits such as reduced systemic toxicity, improved tumor clearance, and better patient compliance remain formulation- and indication-dependent and require robust evidence. These benefits need strong proof to support them. Before these advanced anticancer patches can be seen as proper substitutes for usual cancer treatments, more research is needed in lab settings, proper testing, checking for safety, and trials in real patients [1,2,4,7,12,14]

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