Review Article

# New therapies in nonmuscle invasive bladder cancer treatment

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## ABSTRACT

**Introduction:** Nonmuscle invasive bladder cancer (NMIBC) remains a very challenging disease to treat with high rates of recurrence and progression associated with current therapies. Recent technological and biological advances have led to the development of novel agents in NMIBC therapy.

**Methods:** We reviewed existing literature as well as currently active and recently completed clinical trials in NMIBC by querying PubMed.gov and clinicaltrials.gov.

**Results:** A wide variety of new therapies in NMIBC treatment are currently being developed, utilizing recent developments in the understanding of immune therapies and cancer biology.

**Conclusion:** The ongoing efforts to develop new therapeutic approaches for NMIBC look very promising and are continuing to evolve.

## INTRODUCTION

Bladder cancer is the 9th most common malignancy in the world, with urothelial carcinoma accounting for 90% of all histological subtypes, and is expected to occur in approximately 79,030 American patients in 2017 alone.[1,2] Nonmuscle-invasive bladder cancer (NMIBC) accounts for about 70% of all bladder cancer and is associated with a >88% survival rate over 5 years. However, up to 70% of NMIBC recur after initial treatment, of which 10%–20% can progress to MIBC.[3] According to the European Organization for Research and Treatment of Cancer (EORTC) risk stratification tables, patients with high-risk NMIBC (T1 with high grade/G3 or carcinoma *in situ* [CIS]) represent a particularly challenging group with an increased 5-year risk of recurrence (up to 80%) and progression (up to 50%).[4]

The high rates of progression and recurrence with current therapies for NMIBC necessitate lifelong active surveillance, making bladder cancer the most expensive cancer to treat from diagnosis to death, as well as driving the need for the development of new therapies in patients with NMIBC.[5] Transurethral resection of bladder tumor (TURBT) with or without intravesical therapy, such as mitomycin C (MMC) or Bacillus Calmette-Guerin (BCG), is the current standard of treatment for NMIBC. Intravesical BCG is commonly used as an adjuvant treatment after TURBT for intermediate-high-risk NMIBC.[6] Local and systemic side effects are common with BCG and can lead to discontinuation of therapy in up to 20% of patients.[7] However, up to 50% of patients fail BCG, significantly increasing the risk of progression and death.[8] Patients who have failed BCG therapy require radical cystectomy with urinary diversion or chemotherapy and radiation, both of which are associated with considerable morbidity. In addition, progression to MIBC portends a grim prognosis as only 50% of patients undergoing radical cystectomy will survive at 5 years.[9] Given that current therapies for NMIBC are associated with high rates of progression and recurrence, definitive therapies

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are associated with considerable side effects and morbidity, and the future potential for a BCG shortage, there is an urgent need for novel agents in the treatment of NMIBC. This study presents a review of the newer therapies being evaluated for NMIBC treatment.

## METHODS

A comprehensive review of existing literature, as well as currently active and recently completed clinical trials in NMIBC, was performed for this review by querying PubMed.gov and clinicaltrials.gov.

## BACILLUS CALMETTE–GUERIN

Bacillus Calmette-Guerin was developed in 1921 as a tuberculosis vaccine; BCG is a live attenuated strain of *Mycobacterium bovis*. Even though it is understood that BCG exerts its antitumor effect through immune activation, the exact mechanism of action has not been fully elucidated. Successful BCG therapy requires an intact immune system and direct contact with live BCG, which is internalized by urothelial and dendritic cells, releasing a number of cytokines, including interleukin-6 (IL-6) and granulocyte-macrophage colony-stimulating factor (GM-CSF).[10,11] Multiple meta-analyses have demonstrated the superiority of adjuvant BCG for preventing recurrences compared to TURBT alone or TURBT plus intravesical chemotherapy.[8]

Despite the efficacy of intravesical BCG for NMIBC, up to 80% of treated patients will suffer a recurrence, and up to 45% may progress to muscle-invasive disease within 5 years.[12] BCG failure refers to NMIBC that recurs or progresses within 6 months of BCG therapy.[13] European Association of Urology and the American Urological Association (AUA) guidelines still recommend radical cystectomy for patients for whom BCG has failed.[14,15]

Contemporary trials are primarily focused on novel therapies as second-line agents for BCG failures, with BCG therapy failing in up to 50% of patients in some series.[16] Novel therapies as alternative first-line agents have also been considered because of concerns about BCGs efficacy and recent shortages of BCG.

## RECOMBINANT BACILLUS CALMETTE–GUERIN

Genetically engineered recombinant BCG (rBCG) strains have been developed to overcome some of the limitations of conventional BCG therapy. Currently, the two major rBCG strategies are T-helper 1 (Th1) cytokine-based rBCG and BCG-subcomponent-based rBCG.

A Th1 immunologic response is essential for BCG to produce its antitumor effect. This has led to the development of genetically manipulated BCG strains to secrete Th1 cytokines as a strategy to enhance its effective therapy. These strategies have included IL-2, IL-12, IL-18, interferon (IFN-$\alpha$), and IFN-$\gamma$ secreting rBCG.[17] Studies have shown these strains can be effective in increasing IFN-$\gamma$ production, improving antigen-specific proliferation, eliciting higher levels of Th1 cytokines, and enhancing antitumor activity.[18-22] Th1 cytokine-based rBCG strains may have the potential of enhancing BCG for treatment of NMIBC; further clinical trials in humans are necessary.

Using nonlive immunologically active BCG subcomponents, including BCG cell wall and various BCG proteins and antigens, is currently being researched as a method for inducing the same immune response as live BCG in the treatment of NMIBC while possibly avoiding live BCG-associated side effects. Compared with the other subcomponents of BCG, the BCG cell wall has been found to be the most potent Th1 response inducer.[23] A 2009 multicenter study showed that intravesically administered mycobacterial cell wall-DNA complex (MCC) may be a safe and effective form of treatment in patients with BCG-refractory CIS of the bladder.[24] A recently completed Phase II/III clinical trial assessing MCC in the treatment of BCG-refractory patients with NMIBC reported significant activity of MCC in these patients with few adverse events. Unfortunately, a Phase III trial evaluating MCC versus MMC for the treatment of BCG-refractory NMIBC closed early due to poor accrual.

## MONOCLONAL ANTIBODIES

Monoclonal antibodies are a novel immunotherapy strategy targeting tumor-associated antigens (TAAs). CDX-1307 is a monoclonal antibody that targets $\beta$-hCG, a TAA elevated in the serum and urine of around 30%–40% of cancer patients which may be associated with advanced disease.[25] CDX-1307 consists of B11, a monoclonal antibody against the mannose receptor of antigen-presenting cells (APCs), fused to $\beta$-hCG. CDX-1307 may be of therapeutic benefit in patients with $\beta$-hCG expressing bladder cancer through the induction of cellular and humoral responses through antigen presentation of $\beta$-hCG on APCs to CD4+ and CD8+ T cells.[26] Sadly, an early Phase II trial failed to complete accrual.

Immune checkpoints refer to co-inhibitory receptors expressed in the tumor microenvironment that attenuate tumor-specific effector cells such as T-cells. In addition to immune checkpoints, other mechanisms through which tumors maintain immune tolerance include maintaining protective cell types and producing soluble molecular factors in the tumor microenvironment. Strategies to overcome immune checkpoints represent a novel approach to overcome cancer-induced immune dysfunction.[27]

T-cell activation and proliferation require two major stimulatory signals. The first signal involves the recognition

of antigen presented on major histocompatibility complex through APCs by the T-cell receptor (TCR). The second signal is provided through interaction between B7 proteins on APCs and CD28 on the T-cell. Cytotoxic T-lymphocyte-associated antigen 4 (CTLA-4) is expressed by activated T-cells under normal circumstances to prevent excessive T-cell proliferation by competing with the CD28 costimulatory receptor for the secondary B7 activation signal provided by the APC. CTLA-4 can also be constitutively expressed within the tumor microenvironment to attenuate tumor-specific T-cell responses.[28] A Phase 3 study showed increased survival in patients with metastatic melanoma receiving ipilimumab, a monoclonal antibody against CTLA-4. A study by Liakou *et al*.[29] showed expression of inducible costimulatory (ICOS), a T-cell specific surface molecule structurally similar to CD28, on peripheral blood CD4+ cells in six pre-cystectomy patients with organ-confined bladder cancer treated with ipilimumab. *In vitro* analysis of these cells showed increased production of IFN-γ as well as an increased effector T-cell to regulatory T-cell ratio.[29] A Phase 1 trial in 12 presurgical patients with localized urothelial cancer showed that ipilimumab was tolerable in 11 patients, with Grade 1 and 2 toxicities such as rash and diarrhea being the most common adverse effects.[30] CTLA-4 inhibitors do have considerable potential toxicities and have not been evaluated yet in NMIBC but have demonstrated activity in metastatic urothelial carcinoma.[31]

Another immune checkpoint being explored for checkpoint inhibition immunotherapy is MPDL3280A, an anti-programmed death-ligand 1 (PD-L1) monoclonal antibody that inhibits the interaction between PD-L1 and its receptor, PD-1 on T-cells.[32] Expression of PD-L1 acts to maintain immune tolerance and prevent autoimmunity by interacting with PD-1 and inhibiting TCR activation.[33] Solid tumors, including urothelial tumors, have been shown to exploit this pathway by expressing PD-L1 to promote immune tolerance.[34,35] PD-L1 acts as a marker for tumor progression and is associated with lower survival rates and its expression on bladder cancer cells was associated with high-grade tumors and was found to be extensively expressed in granulomas of recurrent tumors.[36,37] In fact, PD-1/PD-L1 expression is found to increase in tumors as they progress from low grade to high grade.[36] MPDL3280A has shown remarkable clinical activity against metastatic urothelial bladder cancer and was not associated with any Grade 4 or 5 adverse events in a recent Phase 1 clinical trial.[32] Other monoclonal antibodies targeting the interaction between PD-1 and PD-L1 include pembrolizumab and atezolizumab and are being evaluated in several ongoing trials.[38] These trials are evaluating the PD-1/PD-L1 inhibitors in BCG-unresponsive disease either as single agents or in combination with BCG. One new novel trial being performed at the National Cancer Institute (NCI) will treat patients with combination immunotherapy consisting of an intravesical fusion protein (Vicinium) with systemic checkpoint PD-L1 inhibition (Durvalumab). However, to date, no data have been published demonstrating the clinical efficacy of monoclonal antibodies as checkpoint inhibitors in NMIBC.[27,38]

## VACCINES

Vaccines are becoming an attractive area of research as a potential therapeutic option in the treatment of NMIBC. Vaccines induce an activated immune response in the body, allowing for the targeting of oncoproteins and TAAs by the body's natural defenses. Using the body's activated immune response to target NMIBC may decrease the risk of tumor escape when compared to monoclonal antibody therapy, which targets a single receptor and its downstream targets. In addition, vaccines do not require continual treatment for NMIBC.

Targets of vaccine therapies are currently being evaluated and include various oncoproteins (cancer testes antigens [CTAs], e.g. MAGE-A3), TAAs (e.g. carcinoembryonic antigen [CEA] and mucin-1), heat shock protein 90B1 (hsp90B1), upregulated receptors on NMIBC cells (e.g. CVA21), and surface peptide antigens. Recent and ongoing clinical trials are exploring the efficacy of vaccine treatment in the setting of BCG naïve patients (recMAGE-A3 and CAVATAK), BCG unresponsive patients (ALT-801 and PANVAC), or both (HS-410).[38]

MAGE-A3 is a CTA expressed in up to 40% of patients with NMIBC, making this an attractive target for therapy.[39] A Phase I trial combining BCG, recMAGE-A3 (a MAGE-A3 vaccine), and adjuvant AS15 (immunostimulant) recently demonstrated "safety and tolerability" in high-grade Ta, T1, or Tis patients and an increase of vaccine-specific T-cells in the bladder.[40] Of note, the vaccine-specific T-cells were only present in the urine of patients who received combination therapy with intravesical BCG. This suggests that combination therapy requires an intravesical treatment to see the effect of vaccination, vaccine-specific T cells, in the urine.

Percutaneous BCG was originally developed as a vaccine against *Mycobacterium tuberculosis* infection.[41] Its anticancer effect has been known since 1959, but it was not until 1976 that BCG was reported to have successfully treated bladder cancer. Nearly 40% of patients treated with BCG will develop positive tuberculin skin tests. In addition, it is documented that patients with a preexisting positive tuberculin skin test have better recurrence-free survival (RFS) rates than those without a positive test after intravesical BCG reported therapy[11] – priming patients with percutaneous BCG seemed to attenuate the immune response. This prompted a current Phase II trial to evaluate the efficacy of percutaneous BCG and intravesical BCG by measuring the complete response rate of therapy at 12 months. The results are pending.

Coxsackievirus A21 (CVA21) (CAVATAK) targets NMIBC by binding CVA21 receptors (intracellular adhesion molecule-1) that are upregulated on NMIBC cells and promote rapid cell lysis through decay-accelerating factor.[42] CAVATAK was further noted to upregulate I-CAM receptors creating a stronger treatment response when combined with intravesical MMC in a recent study. This Phase II trial reported that treatments were well tolerated and a specific antitumor immune response was noted in 16 patients' pretransurethral resection of the bladder tumors.[43]

ALT-801 is a fusion protein (IL-2 and TCR) that recognizes surface antigens derived from p53 *in vivo* in p53+/HLA-A2+ tumor xenografts.[43] A current Phase Ib/II trial is investigating safety, tolerability, and cancer recurrence rates up to 13 weeks in patients with high-grade Ta, T1, or Tis NMIBC treated with ALT-801 and IV gemcitabine.

PANVAC is a poxviral vector-based vaccine that contains the TAAs CEA and mucin-1 as well as three T-cell co-stimulatory molecules. There is a current ongoing Phase II trial studying the 12-month RFS of two treatment arms in BCG-refractory patients: the combination of PANVAC and BCG and BCG only. Preliminary immune analysis data for the first 16 patients were reported at the AUA annual meeting in 2017. In the PANVAC and BCG combination arm, an increase in CD8 T-cells, antigen-specific T-cell responses to CEA and MUC-1, and an increase in an antigen-specific T-cell response to brachyury were reported. The T-cell response to brachyury is of particular importance as an immune response against brachyury may potentially trigger an antitumor response cascade as brachyury is a transcription factor involved in epithelial to mesenchymal transition. There was no difference in CD4 cell counts or RFS between the two arms.[44]

HS-410 (Vesigenurtacel-L) is a vaccine containing multiple TAAs (e.g. hsp90B1 and gp96). GP96 antigen complexes are known to be efficient stimulators of CD8+ cytotoxic T-cells. HS-410 and BCG may have synergistic effects in the treatment of NMIBC. The Phase II clinical trials were recently reported at a major meeting evaluating the primary endpoint of 1-year RFS across three study arms. Preliminary results of the 78 patients enrolled reported that RFS rates for BCG and low-dose HS-410, BCG, and high-dose HS-410, and BCG and placebo were 65.4%, 65.45%, and 76.9%, respectively. The investigators concluded that HS-410 was well tolerated and no adverse events related to the vaccine were reported. There was no statistically significant difference in RFS between HS-410 and placebo; however, only the patients exposed to vaccine developed immune responses to tumor-associated peptides.[45]

Although no clinical difference was seen in the three vaccine trials highlighted (MAGE-A3, PANVAC, and HS-410) in patients with or without BCG, all demonstrated that vaccines in combination with BCG led to an "increased immune response." As additional study results are presented, we will be able to better understand the context, in which vaccines may play a role in the treatment of NMIBC. It may be safe to conclude that vaccines may have little efficacy or immunological enhancement as monotherapy.

## CYTOTOXIC THERAPY

Epirubicin is a doxorubicin derivative commonly used as a chemotherapy agent in Europe and Japan post-TURBT, especially in patients with low and intermediate-risk NMIBC.[38] However, despite an increased risk of toxicity, BCG immunotherapy has been shown to be superior to epirubicin in prolonging time to the first recurrence, preventing distant metastasis, and improving overall survival in patients with intermediate- and high-risk NMIBC.[46] A Phase IV trial is currently recruiting participants to evaluate the efficacy of immediate intravesical instillation of epirubicin after TURBT in patients with intermediate and high-risk NMIBC by measuring the rates of recurrence, progression, and/or death from cancer within the 1$^{st}$ year after complete TURBT.

The antitumor agent MMC, which exerts its effects through DNA alkylation, has been found to improve recurrence rates (42% vs. 58%) when combined with BCG therapy in a Phase II trial.[47] In an ongoing Phase III trial, the efficacy of MMC and BCG combination intravesical therapy in high-risk patients with NMIBC is being evaluated by assessing the disease-free survival over 5 years. A recently completed early Phase I clinical trial found that external deep pelvic hyperthermia is a safe and effective method of heating the bladder in patients undergoing intravesical MMC. In this study, 15 patients with BCG-refractory NMIBC underwent external deep pelvic hyperthermia combined with intravesical MMC. The reported adverse events were all minor (Grade 2 or less), with no systemic toxicity observed.[48]

Even though multiagent therapy is regularly used systemically in patients with metastatic disease, there is growing interest in using multiple agents intravesically, and recent studies have shown encouraging outcomes. For example, disease-free rates of 54% at 1 year and 34% at 2 years have been demonstrated in one study of the utility of the intravesical combination of gemcitabine with docetaxel in 45 patients with NMIBC recurrence after BCG therapy[49] and disease-free rates of 50% at 1 year have been demonstrated in a multi-institutional retrospective study of high-risk patients with NMIBC treated with sequential intravesical gemcitabine followed by MMC.[50] A Phase I trial is currently underway to evaluate the safety of an intravesically administered a multidrug regimen of cabazitaxel, gemcitabine, and cisplatin (CGC) in the treatment of BCG-resistant NMIBC. Early results show that

intravesical CGC appears to be well tolerated in patients with NMIBC, with five patients experiencing at least one Grade 1 toxicity and the remaining four patients experiencing at least one Grade 2 toxicity.[51]

## TARGETED THERAPY

Oportuzumab monatox (OM) is a recombinant fusion protein of humanized antiepithelial cell adhesion molecule antibody linked to *Pseudomonas exotoxin*. In high-grade tumors, including bladder cancer, the epithelial cell adhesion molecule surface antigen is usually overexpressed, allowing OM to specifically target tumor cells.[52] Two OM dosing strategies were evaluated in a Phase II trial in BCG-refractory CIS patients and found complete response rates of 26.7% and 15.6% at 6- and 12-month intervals, respectively.[52] This has prompted a new Phase I trial that will open at the NCI this fall for BCG unresponsive HG NMIBC that will treat patients with intravesical OM combined with systemic durvalumab. The trial will evaluate safety, but secondary endpoints will look at efficacy and immunologic correlates.

Other examples of targeted therapy include BGJ398, sunitinib, enzalutamide, ethacrynic acid, and tamoxifen. BGJ398 is a tyrosine kinase inhibitor targeting FGFR3 and found to be activated in approximately 75% of all cases of NMIBC.[53] A Phase I/II trial to evaluate the safety and efficacy of oral administration of BGJ398 in BCG-refractory patients with NMIBC is currently underway. Sunitinib functions by inhibiting various key tyrosine kinases including vascular endothelial growth factor receptors 1, 2, and 3.[54] The combination of oral sunitinib and intravesical BCG is being evaluated in high-risk patients with NMIBC in an ongoing Phase II trial. The most recent data from the study show that 72% of patients have a complete response at 3 months with 77% RFS and 100% progression-free survival at 24 months.[55] Enzalutamide, an androgen receptor (AR) antagonist that has been used in the treatment of metastatic castrate-resistant prostate cancer, has been shown to inhibit bladder cancer proliferation, migration, and invasion in AR+ cell lines.[56] The efficacy of enzalutamide in preventing bladder cancer recurrence in patients with both AR+ or AR$^-$ NMIBC will be evaluated by looking at recurrence rate over a 12-month period in an ongoing Phase 2 study. Ethacrynic acid is recognizable as a commonly used loop diuretic. However, it has also been shown to be cytotoxic through inhibition of glutathione S-transferase and Wnt/β-catenin signaling, and dysregulation of which has been implicated in various tumors including bladder cancer.[57,58] The recently completed Phase I trial aims to evaluate the safety and efficacy of ethacrynic acid when given immediately before TURBT in patients with NMIBC. Tamoxifen is a nonsteroidal selective estrogen-receptor modulator mainly used in the treatment of breast cancer. However, a preclinical study has shown that it is also effective in reducing the incidence of bladder cancer in mice.[59] An ongoing Phase II trial is evaluating the efficacy of oral tamoxifen citrate in patients with low-to-intermediate-risk NMIBC by assessing for the clinical response of the marker lesion over a 4-year period.

## IMMUNOMODULATORS

TMX-101 is a synthetic toll-like receptor-7 agonist (TLR7) (imidazoquinoline) that functions as an immune modulator in the MyD88 pathway.[60] Imiquimod (an imidazoquinoline) is an existing topical treatment for basil cell carcinoma, actinic keratosis, and condylomas. It has been modified for intravesical use and is being investigated in the treatment of NMIBC as TLR7 is also found in bladder cancer.[60,61] A 2013 single-center Phase I trial found TMX-101 to be safe with low systemic effects and mild side effects typically limited to the genitourinary tract.[62] A 2017 prospective nonrandomized, multicenter, Phase II trial demonstrated continued safely and an immune response as evidenced by increased levels of urinary cytokines (IL-6 and IL-18) in 12 Ta to T1 patients. In addition, 2 out of 12 patients reported negative bladder biopsies at 6-week follow-up posttreatment.[63]

ALT-803 is a recombinant immunomodulating fusion (IL-15 analog + IL15-RaFc) protein that is 25 times more active than IL-15 *in vivo* and a demonstrated ability to activate natural killer and CD8+ T-cells through local cytokines.[64] In a rodent NMIBC model, ALT-803+ BCG was shown to reduce tumor burden (by 46%), produce a local cytokine response (IL-1α, IL-1 β, and RANTES), activate NK cells, and reduce angiogenesis (by 76%) when compared to the control group.[64] ALT-803+ BCG was shown to be more effective than either BCG or ALT-803 alone. A Phase I and II study is currently underway. The group undertaking the clinical trials released a case report ahead of their published Phase I and II results. In it, a 92 man with a history of Ta high-grade NMIBC and recurrent disease post-BCG therapy remains cancer free 19 months after treatment with ALT-803+ BCG.[65]

Lenalidomide, an immunomodulator, is a thalidomide derivative with a known tumoricidal activity that has shown improved time to progression and increases in overall survival in relapsing multiple myeloma Phase III trials.[66,67] These properties make it an attractive potential treatment option for NMIBC, for which it has undergone a Phase I murine-based clinical trial. They reported that lenalidomide + BCG produced significant antitumor effects: increasing cell death, decreasing tumor volume, and reducing angiogenesis in tumors.[66] There is currently an ongoing Phase II trial.

Atezolizumab is a humanized monoclonal antibody capable of selectively antagonistically binding programmed death ligand-1 (PD-L1) on tumor cells. PD-L1 decreases T-cell

activity and is broadly expressed across a wide array of malignancies, providing survival benefits for tumors overexpressing PD-L1.[68,69] One multicenter, single-arm, Phase II study demonstrated that atezolizumab was well tolerated and provided antitumor responses in 310 patients with locally advanced or metastatic urothelial carcinoma who previously failed platinum chemotherapy. In addition, patients' tumor PD-L1 levels were measured which showed that the higher the expression of PD-L1, the more likely the patient responded to treatment.[68]

Pembrolizumab (MK-3475) is a humanized monoclonal antibody that binds the PD-L1 receptor but this time on the immune (T) cells – preventing them from interacting with their ligands.[70] In a Phase Ib clinical trial, pembrolizumab was reported to be safe and tolerated well in 33 patients.[71] In a 2017 randomized Phase III trial, pembrolizumab showed significantly longer overall survival than chemotherapy (10.3 pembrolizumab and 7.4 chemotherapy) with less adverse events from treatment in 542 patients with recurrent advanced urothelial cancer postplatinum chemotherapy treatment.[72] As a result, pembrolizumab was recently approved by the Food and Drug Administration as a second-line treatment for metastatic urothelial carcinoma.[73] Several PD-1/PD-L1 inhibitors such as durvalumab, atezolizumab, and pembrolizumab are being evaluated in clinical trials for nonmuscle invasive disease given their activity in metastatic urothelial cancer.

## GENE THERAPY

CG0070 is a recombinant adenovirus that allows for selective viral replication in tumor cells and local production of GM-CSF by targeting the often deregulated retinoblastoma tumor suppressor pathway.[74] The intravesical instillation of CG-0700 has been shown to be safe, with a complete response rate of 48.6% at 10.4 months.[74] An ongoing Phase III trial is looking at complete response lasting at least 12 months to evaluate the efficacy of CG-0070 in patients with NMIBC who have failed BCG therapy.

rAd-IFN/Syn-3 (Instiladrin) is a nonreplicating recombinant adenovirus vector containing the human IFN alpha-2b (IFNα2b) gene and the addition of Syn-3 significantly augments adenoviral-mediated transduction of normal urothelium and NMIBC, resulting in high, durable urine IFNα concentrations and tumor regression.[75] The Phase I and II trials involving rAd-IFN/Syn-3 have demonstrated detectable levels of IFN-α in urine, as well as RFS, was 35% at 12 months in the Phase II trial.[75,76] The current Phase III trial evaluates the efficacy of rAD-IFN/Syn-3 in BCG-unresponsive patients with NMIBC by looking at the event-free survival at 12 months.

VPM1002BC is a live genetically modified *M. bovis* BCG that expresses the bacterial toxin listeriolysin. This recombinant form of BCG has demonstrated higher levels of the antigen-specific memory T-cell and T follicular helper T cells associated with specific antibody responses. This is thought to be due to improved antigen presentation as a result of the pore-forming ability of the toxin.[77] An ongoing Phase I/II trial is evaluating the safety, tolerability, and efficacy of intravesical installation of VMP1002BC in patients with recurrent NMIBC.

## RADIATION THERAPY

Trimodality therapy (TMT) refers to TURBT followed by chemoradiation involving agents such as 5-FU, MMC, and cisplatin. Extensive studies have shown similar overall survival with TMT as radical cystectomy in patients with muscle-invasive bladder cancer.[78] Recent studies have shown that TMT may also be effective in the recurrent high-grade T1 tumor, with one study reporting an 88% complete response rate and a 19% progression rate in patients with T1G3 NMIBC tumors.[79] An ongoing Phase II trial (RTOG 0926) aims to evaluate the efficacy of TMT in patients with NMIBC with persistent T1 disease who have failed BCG therapy by evaluating the rate of freedom from radical cystectomy at 3 years.

Radiation therapy (RT) amplifies tumor immunogenicity and may be capable of inducing or potentiating a systemic antitumor immune response. Immunoradiotherapy (IRT) may also induce immune-inhibiting responses in the microenvironment (increase of PD-L1, TGF-β, or inhibitory immune cells such as regulatory T-cells, alternatively activated macrophages, and myeloid-derived suppression cells [MDSCs]) that act against the effective antitumor response. Preclinical synergistic local (radiosensitizing immunotherapy) and distant antitumor activity were shown with the combination of irradiation and anti-PD-L1. This effect was associated with a decrease in local accumulation of tumor-infiltrating MDSC that inhibits of T-cell function.[80]

One of the first clinical results assessing an immune checkpoint blocker with concomitant RT was recently completed and found that concurrent palliative RT with durvalumab was well tolerated in ten patients with histologically or cytologically confirmed inoperable or metastatic cancers.[81] A combined Phase Ib/II study of concurrent durvalumab and RT followed by adjuvant durvalumab in patients with urothelial cancer (T2-4, N0-2, MO) of the bladder is currently underway with primary outcome measures of safety assessment, progression-free survival after 1 year, and disease control rate after 15 months.

There are numerous uncertainties associated with IRT. The timing and the radiation dose per fraction seem to be important parameters determining the modulation of the immune response. Fractionated RT could be more

appropriate than single dose RT. There is also an unmet need of surrogate markers to predict or assess the immune response. PD-L1 "positive" tumors have shown trends toward increased rates of response to PD-L1 blockade.[68]

## INTRAVESICAL DRUG DELIVERY SYSTEMS

Nanoparticle albumin-bound paclitaxel (nab-Paclitaxel) was investigated in a Phase II trial using patients with recurrent NMIBC (Tis, Ta, and T1) after BCG therapy and a Phase III trial currently underway. Paclitaxel stabilizes microtubules, arresting them at $G_2$-M in the cell cycle. After adding albumin (creating nab-paclitaxel), the nanoparticle's solubility is increased fivefold and can use albumin receptor-mediated transport for increased delivery to tumor cells.[38,82] Long-term follow-up data from the Phase II trial (medium 41-month follow-up) on 28 patients showed cancer-specific survival rate of 91% (18% disease free) at 5 years.[82]

Some drug targets appear promising but their short half-lives limit exposure to the urothelium and render them ineffective. A few trials explore c-administering treatment medication with other compounds that target the mucous membrane of the bladder to add synergistic effects. A novel trial used Syn 3 (enhancer: binding and stabilization) to aid in rAd-IFN (recombinant adenovirus producing interferon alpha-2b) intravesical delivery in refractory NMIBC patients. Commercially known as Instiladrin (rAd-IFN with Syn3), Phase II results showed that rAd-IFN with Syn3 was tolerated well with no Grade 4 or 5 adverse events, and 35% (14 patients) were free of high-grade recurrence at 12 months (AA).[83] Other mucoadhesive nanogels are beginning to be investigated in the delivery of NMIBC delivery of therapy. Hydrophobic drugs are known to have greater penetration of the urothelium than hydrophilic and thus creating hydrophobic carriers of drugs may produce better treatment results.[84] Mucoadhesive nanogels showed promise in animal models, reportedly aiding uptake of docetaxel through endocytosis and releasing 75% of loaded drug over 9 days.[85]

## HYPERTHERMIA TREATMENT OPTIONS

Combining NMIBC treatment with external heat before administration has shown that heat + mitomycin-C is more efficacious than either treatment alone.[86] Combined chemohyperthermia (CHT) for the treatment of NMBIC as an invasive procedure was first reported safe and reproducible in 2014, with hyperthermia doses of 42°C ± 2°C for 40–60 min through BSD-2000 hyperthermia system (eternal radiofrequency).[48,87] A randomized controlled trial comparing CHT + MMC against BCG as an adjuvant therapy in intermediate- and high-risk NMIBC showed that CHT is safe and effective with a significantly higher RFS rate at 24 months.[88]

## CONCLUSION

NMIBC remains a very challenging disease to treat not only because of the high rates of recurrence and progression associated with current therapies but also due to the extensive follow-up necessary after diagnosis and initial treatment. As discussed in this review, however, many novel therapies for NMIBC are currently being developed and tested in clinical trials ranging from vaccines to immunomodulators and targeted therapies. The ongoing efforts to develop new therapeutic approaches for NMIBC look very promising and may help develop a new paradigm of NMIBC treatment in the near future.

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